POLYCULTURE OF CAGED CHANNEL CATFISH AND

TILAPIA AUREA IN SMALL PONDS

By

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PREFACE

Aquaculture is gaining importance in the world as a means to produce relatively inexpensive high quality protein. Although current United States production is generally restricted to large-scale enterprises, the potential exists for aquaculture, like the vegetable garden, to become a part of many small farms and urban backyards. It is in this spirit that the caged polyculture experiment has been undertaken. The overall objective is to increase production from small-scale aquaculture and thus lower production expenses. Funds for this project were provided by the Langston University Research Program, CSRS-OKLX-8085-15-5, through the Department of Agriculture in cooperation with the Oklahoma Cooperative Fisheries Research Unit and Oklahoma State University.

I would like to thank my Graduate Committee--Dr. O. Eugene Maughan, Dr. Margaret S. Ewing and Dr. William D. Warde for their personal assistance, review of manuscripts and statistical guidance. I would also like to thank Glen E. Gebhart and Donald P. Schwartz for their daily assistance and cooperation. I extend my gratitude to Marcia R. Roi and Jules D. Bond for their moral support and to my parents, Bill and Barbara Williams, for their love and encouragement.

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CHAPTER I

PRELIMINARY INVESTIGATION INTO THE OPTIMAL RATIO OF CAGED CHANNEL CATFISH AND TILAPIA IN SMALL PONDS

Introduction

Culture of fish potentially offers the farm pond owner in Oklahoma an added source of income. The extent of this opportunity is seen by the fact that Oklahoma was one of only three states which had over 150,000 ponds constructed by the Soil Conservation Service (Modde 1980). These ponds currently support generally poor sport fisheries which are difficult to manage (Snow 1975; Bennett 1971). Traditional open water pond culture is not generally applicable to Oklahoma ponds because they can not be drained and are too deep or do not have the smoothly contoured sides and bottom necessary for efficient seine harvest (Toetz 1978). Therefore, cage fish culture appears to provide an opportunity to realize additional income but avoid the problems of open water culture.

The applicability of cage culture to Oklahoma farmers is evident upon review of its advantages (Schmittou 1970; Collins 1978):

1) Fish can be cultured in many types of water bodies, including farm ponds, as long as an adequate oxygen supply and toxic waste buffering capacity are maintained.

2) Fish can be intensively cultured where otherwise a lower level of open water culture would have to be practiced due to inefficient harvest.
3) Cage culture can complement other culture or management practices, such as a sport fishery, fee fishery, or bait culture operation in some water bodies.
4) The health of caged fish is easily observed, and the fish culturist has the opportunity to take early action against health related problems.
5) Treatment of disease and parasite problems is easier and less expensive in cages than in open water culture.
6) Fish can be easily and completely harvested by cage removal. The cage may also be partially harvested as faster growing individuals reach marketable size or as market demand increases.
7) A relatively low investment is required if an existing body of water is used.

However, the potential culturist must also be aware of the disadvantages of cage culture (Schmittou 1970; Collins 1978):

1) Cage construction cost may be high because durable and rust resistant materials are expensive.
2) A nutritionally complete floating feed is required since the caged fish can not forage for natural food items.
3) Aeration equipment may be necessary since caged fish are more vulnerable to low dissolved oxygen, high carbon dioxide, and high ammonia levels than are uncaged fish. For example, Newton (1980) stated,

> The major disadvantage of confining fish to cages

> continues to be the periodic occurrence of low levels of dissolved oxygen. Catfish in cages will succumb to low oxygen more readily than fish which are free in a pond. This statement is as true in 1980 as it was 10 years ago and remains the major obstacle to cage culture (p. 32).

4) Vandalism to fish and cages may occur if precautions are not taken. For example, a cage culture facility in southern Oklahoma was recently completely destroyed by vandals (Rudolph McGeehee, pers. communication).

5) Parasites and bacterial diseases are transmitted quickly among caged fish.

After consideration of these advantages and disadvantages, Collins (1978) concluded that $823/ha could be earned from a channel catfish (Ictalurus punctatus) cage culture operation in southeastern Oklahoma. This estimate may be conservative because of Collins's concern about exceeding a carrying capacity of 1680 kg/ha in any impoundment not receiving inflow of water or supplemental aeration. As the result of these recommendations Collins (1978) also recommended that only bodies of water greater than 2 surface ha be used if more than 1235 fish per surface ha were to be raised in cages. In ponds less than 2 ha, Collins's recomendation of a maximum of 1235 caged fish per ha would limit production to approximately 550 kg/ha/year. However, Schmittou (1970) produced up to 1728 kg/ha of channel catfish in a 0.5 ha pond and Lovell (1972) harvested 1626 kg/ha in a 2.0 ha pond. It is therefore reasonable to suggest that production of 1680 kg/ha in ponds less than 2 ha is feasible if precautions are taken to alleviate potential oxygen related problems.

The possibility of high fish mortality in small ponds can be reduced by suspending feeding under low oxygen levels or substituting a species which is tolerant of low water quality such as the cichlid *Tilapia aurea* (tilapia) for more commonly used species such as channel catfish. Although tilapia readily consume prepared feeds, their natural planktivorous feeding habits may allow them to provide additional production. For example, Armbrester (1972) reported that caged tilapia stocked at $500/m^3$ produced up to $44.8\ kg/m^3$ in 10 weeks in fertilized ponds with no supplemental feeding.

A major disadvantage to pond culture of tilapia is excessive reproduction. In open pond systems the large number of young results in stunted populations with a low percentage of harvestable fish. For example, Bowman (1977) reported a harvestable yield of only 25.6 percent in unfertilized ponds. Cage culture provides one solution of this problem because reproductive products are lost through the cage mesh and do not remain viable (Pagon-Font 1975).

The other major advantage of herbivorous fish culture is increased flesh per area of water. Bowman (1977) reported net yields of tilapia up to 3015 kg/ha in open pond culture and similar values should be possible with cage culture. There is, however, little published information on the feasibility of commercial cage production of tilapia. The major limitation of herbivorous fish culture in the United States appears to be consumer acceptance. Therefore it seems more reasonable to combine the culture of the hardy herbivorous fish with that of one more traditionally used for food and to reduce densities to minimize unwanted mortality.

The purpose of this study is to generate base-line data which might suggest optimal channel catfish-tilapia stocking ratios.

Methods and Materials

I. Description of Study Sites: The optimum stocking ratio of channel catfish and tilapia was investigated in 0.1-ha and 0.4-ha ponds managed by the Oklahoma Cooperative Fisheries Research Unit. These ponds are located on Oklahoma State University property below Lake Carl Blackwell, 12 km West of Stillwater, Oklahoma.

II. Experimental procedures: Fish were stocked in floating 1-m^3 cylindrical, plastic mesh cages. The cages were placed in the deepest area of the pond (1.3 m in the 0.1-ha ponds and 1.8 m in the 0.4-ha ponds).

Temperature and dissolved oxygen in the ponds were measured weekly at approximately 0930 with a Yellow Springs Instrument Company oxygen and temperature probe.

All fish were fed a complete 32 percent protein, floating, pelleted (1-cm diameter) ration. Initially fish were fed at 3 percent of body weight per day but subsequently they were fed *ad libitum* once per day for 10 minutes. The change in feeding schedule was necessitated by the slowdown in feeding following sampling and weighing fish. (Appendix D, Feeding Rationale).

The optimal stocking ratio of channel catfish and tilapia was examined by stocking a total of 450 fish per cage in the following proportions:

Catfish to Tilapia Ratio	Number of Catfish	Number of Tilapia
4:1	360	90
3.5:1	350	100
3:1	338	112
2.5:1	321	129
2:1	300	150
1.5:1	270	180
1:1	225	225
1:2	150	300

Each cage was replicated once for a total of 16 cages. Three cages were placed in each of four 0.4-ha ponds and one cage in each of four 0.1-ha ponds. Cages were distributed among the ponds to minimize differences of expected total weight of fish per ha between ponds.

Cages were initially stocked with channel catfish fingerlings (mean weight 13.3 g) on May 6-8 but mortality (from a blue-green algal bloom) and equipment failure (a tear in a cage) necessitated restocking of 3 cages on May 28-29 with 19.6 g fingerlings.

Tilapia obtained from Horseshoe Lake, Harrah, Oklahoma, were stocked in cages from May 9 to June 10; extensive mortality necessitated an extended stocking period. Mean weight of tilapia on June 10 ranged from 120.0 to 199.3 g. Harvest dates ranged from August 18-29. At harvest 30 channel catfish from each cage were individually weighed to the nearest gram. The remaining fish were batch weighed. Due to heavy mortality of fish, linear regression was used to analyze the data for trends.

Results

Linear Regression Correlations

The final ratios of channel catfish and tilapia and total numbers of fish per cage were not identical to the initial ratios and numbers stocked. These differences were principally due to initial heavy mortality of tilapia (Table 1). The tilapia were in poor condition when obtained; average condition factor (K factor) was 1.78 at stocking and 1.96 at harvest.

There was no significant correlation between the ratio of channel catfish to tilapia and total net production ($r = -0.390$) ($P = 0.168$)

Table 1. Production data from the channel catfish - tilapia ratio cages. (1980).

Cage	No. of catfish	No. of tilapia	Total number	Ratio	Amount feed (kg)	Net prod. catfish (kg)	Net. Prod. tilapia (kg)	Net. Prod. total (kg)
IN	336	31	367	10.8:1	50.147	35.957	1.343	37.306
IM	290	80	370	3.6:1	39.285	30.396	0.440	30.836
IS	150	98	248	1.6:1	34.290	15.257	10.322	25.579
2N	256	109	365	2.3:1	64.170	43.918	8.691	52.609
2M	261	147	408	1.8:1	64.930	36.137	9.275	45.412
2S	189	128	317	1.5:1	51.302	32.411	2.973	35.384
3N	325	87	412	3.7:1	70.705	34.929	12.774	47.705
3M	312	115	427	2.7:1	81.527	29.884	7.628	37.512
3S	147	272	419	0.5:1	87.537	16.129	31.367	47.496
4N	297	104	401	2.9:1	70.683	31.622	9.655	41.277
4M	276	150	426	1.8:1	71.130	25.651	12.171	37.822
4S	209	211	420	1:1	80.076	20.206	22.417	42.623
6	360	73	433	4.9:1	43.743	29.487	2.267	31.754
7	350	37	387	9.5:1	47.068	30.061	5.353	35.414
9	332	78	410	4.3:1	56.778	29.249	3.140	32.389

Table 1. Continued.

Cage	F.C.E.*	Mean wt. (g) per catfish	(%) Survival catfish	Mean wt. (g) per tilapia	(%) survival tilapia
1N	1.34	120.3	99.4	166.0	27.7
1M	1.27	118.1	96.7	129.8	53.3
1S	1.34	123.0	92.7	198.4	32.7
2N	1.22	184.8	79.8	227.1	84.5
2M	1.43	151.7	96.7	218.0	81.7
2S	1.45	184.7	84.0	161.6	56.9
3N	1.48	120.7	96.2	249.0	77.7
3M	2.17	109.6	97.2	192.8	89.2
3S	1.84	123.0	98.0	233.4	90.7
4N	1.71	119.7	99.0	193.5	69.3
4M	1.88	106.2	100.0	221.9	83.3
4S	1.88	109.9	92.9	241.6	93.8
6	1.38	95.2	100.0	216.5	81.1
7	1.33	99.1	100.0	317.2	37.1
9	1.75	101.3	94.9	176.6	78.0

*F.C.E. = Feed Conversion Efficiency.

and graphic analysis did not reveal an optimum stocking ratio. There was also no significant correlation between the ratio of the two species and individual production of either ($r = -0.348$) ($P = 0.223$) channel catfish or ($r = 0.029$) ($P = 0.922$) tilapia. In addition there was no significant correlation between the ratio of the two species and the feed conversion efficiency ($r = -0.448$) ($P = 0.108$). However, the value does strongly indicate a trend toward superior feed conversion efficiencies as the ratio of channel catfish to tilapia is increased. Fish in cages with extremely high ratios of channel catfish to tilapia (10.8:1 and 9.5:1) exhibited good feed conversions (1.34 and 1.33) whereas those with low ratios of channel catfish to tilapia (0.5:1 and 1:1) exhibited poorer but still acceptable feed conversion efficiencies (Table 1).

The total number of fish per cage appeared to have a greater effect on net production and production per individual channel catfish than any other variable. Although the relationship was not significant ($r = 0.094$) ($P = 0.749$) (Figure 1), the inverse relationship between total number of fish per cage and individual channel catfish production was significant ($r = 0.709$, $P = 0.005$). This trend seems to indicate that individual production decreased as the total number of fish per cage increased (Figure 2). The total net production of channel catfish also tended to decrease as the total number of fish increased (Figure 3). This trend was statistically significant at ($P = 0.086$) ($r = -0.475$). In contrast, the total number of fish per cage was not significantly correlated with either individual or net tilapia production ($r = 0.348$) ($P = 0.223$) and ($r = 0.586$, P. $= 0.028$) (Figure 4). In addition the positive correlation (Figure 5) between the number of

Figure 1. Relationship between total net production and the total number of fish/cage.

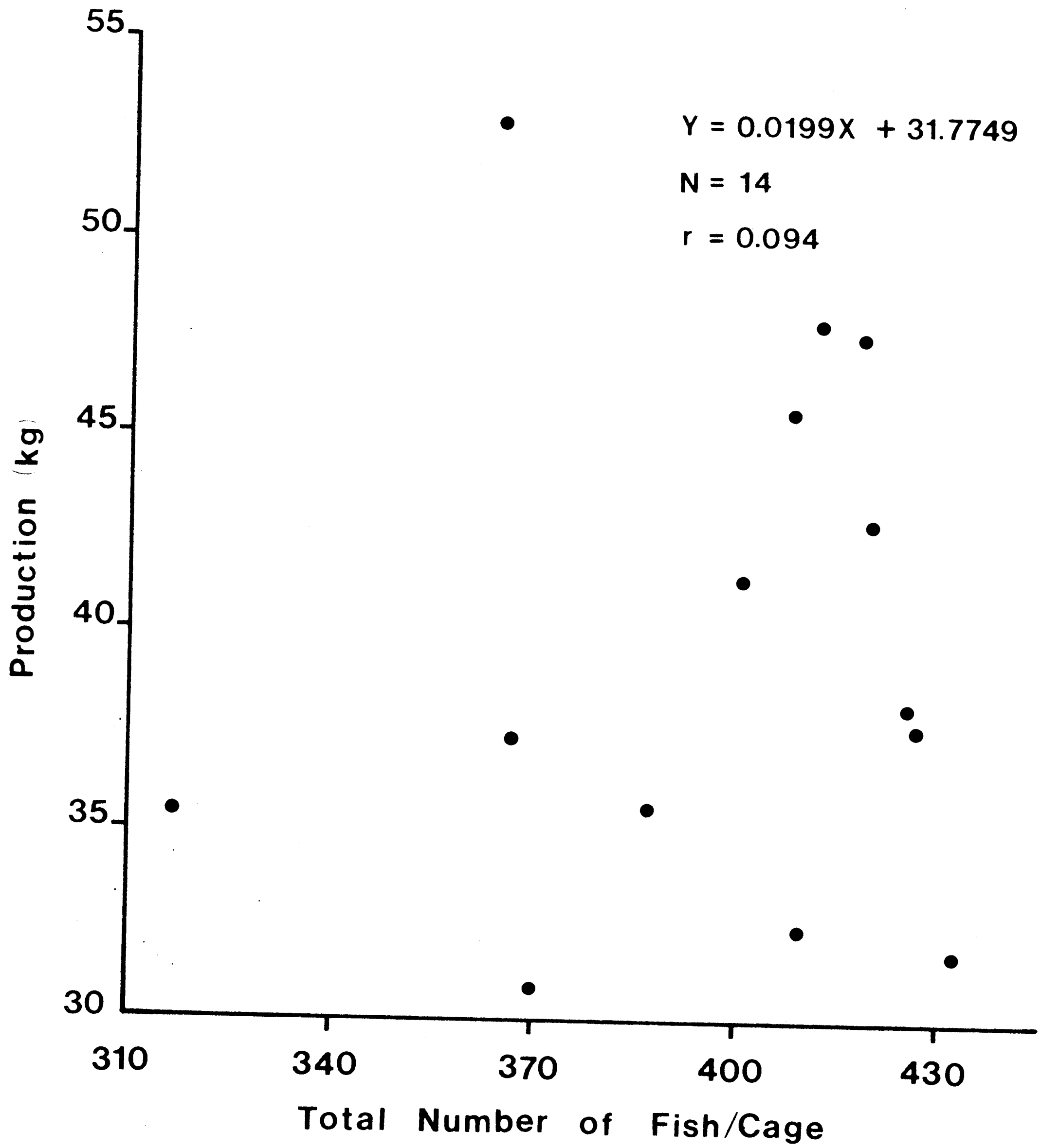

Y = 0.0199X + 31.7749
N = 14
r = 0.094
55
50
45
40
35
30
Production (kg)
310
340
370
400
430
Total Number of Fish/Cage

Figure 2. Correlation between production/catfish and the total number of fish/cage.

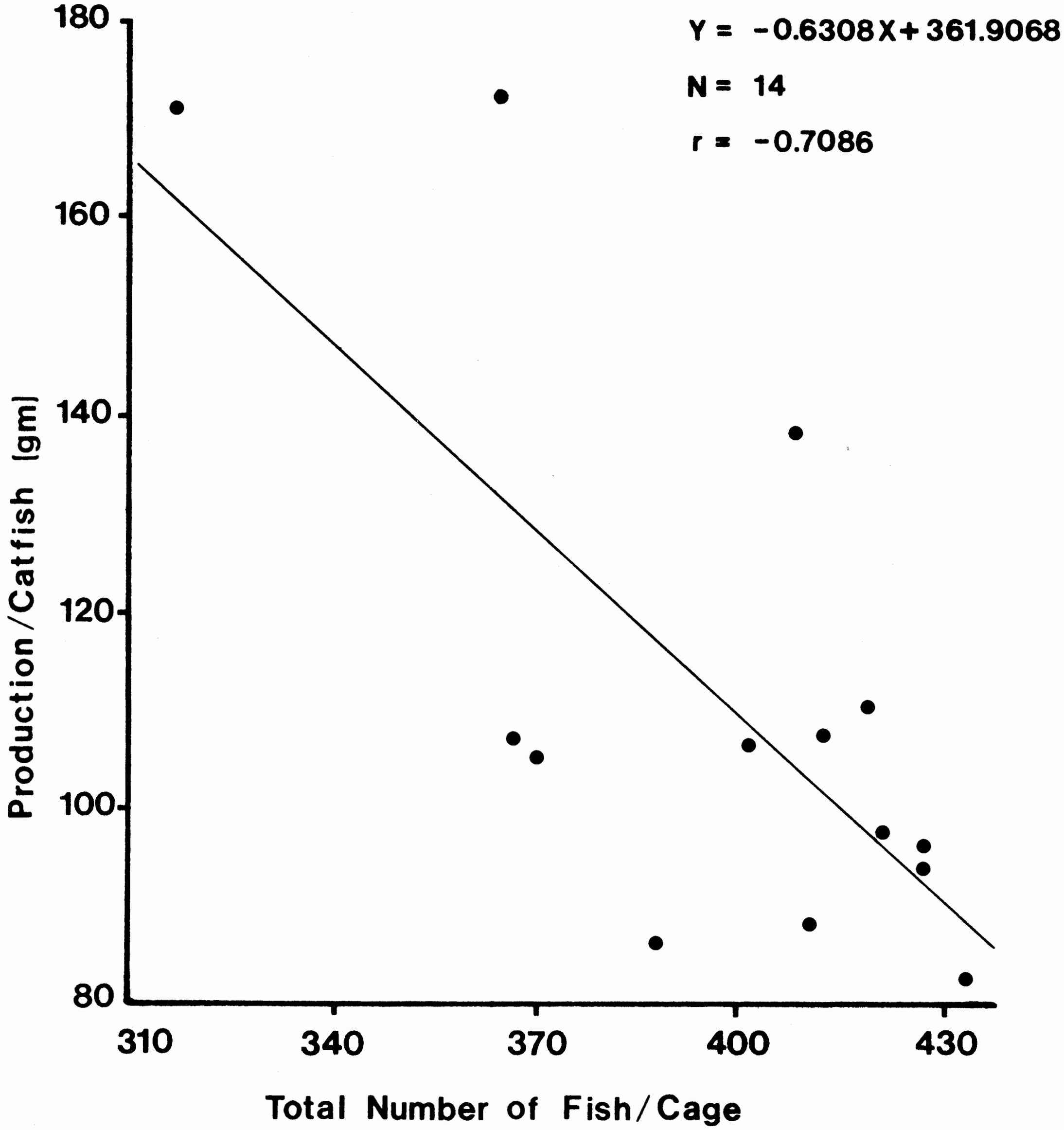
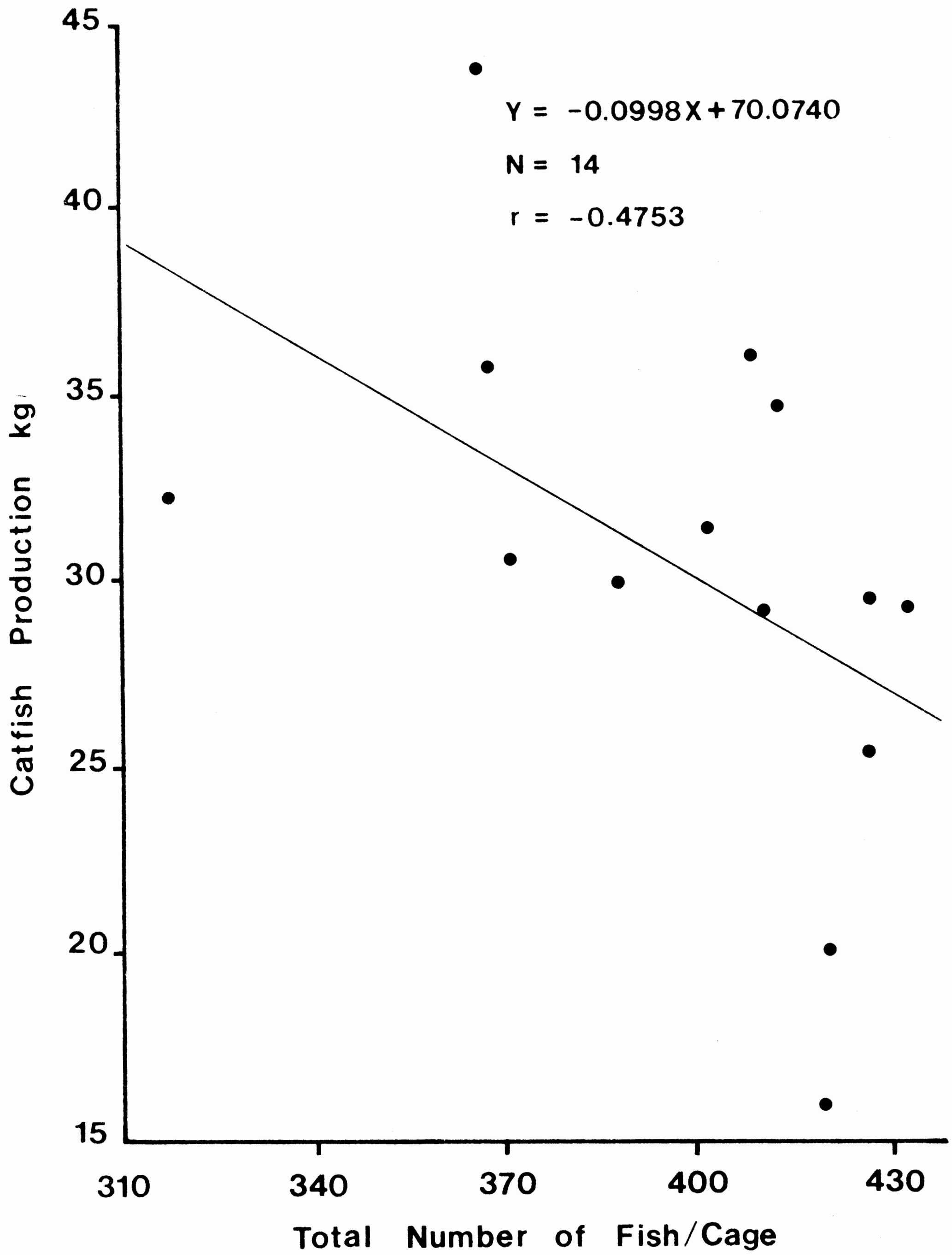

Y = -0.6308X+ 361.9068
N = 14
r = -0.7086
180
160
140
120
100
80
Production/Catfish (gm)
310
340
370
400
430
Total Number of Fish/Cage

Figure 3. Correlation between catfish production and the total number of fish/cage.



45
40
35
30
25
20
15
Catfish Production kg
Y = -0.0998X + 70.0740
N = 14
r = -0.4753
310
340
370
400
430
Total Number of Fish/Cage

Figure 4. Correlation between feed conversion ratio and the total number of fish/cage.

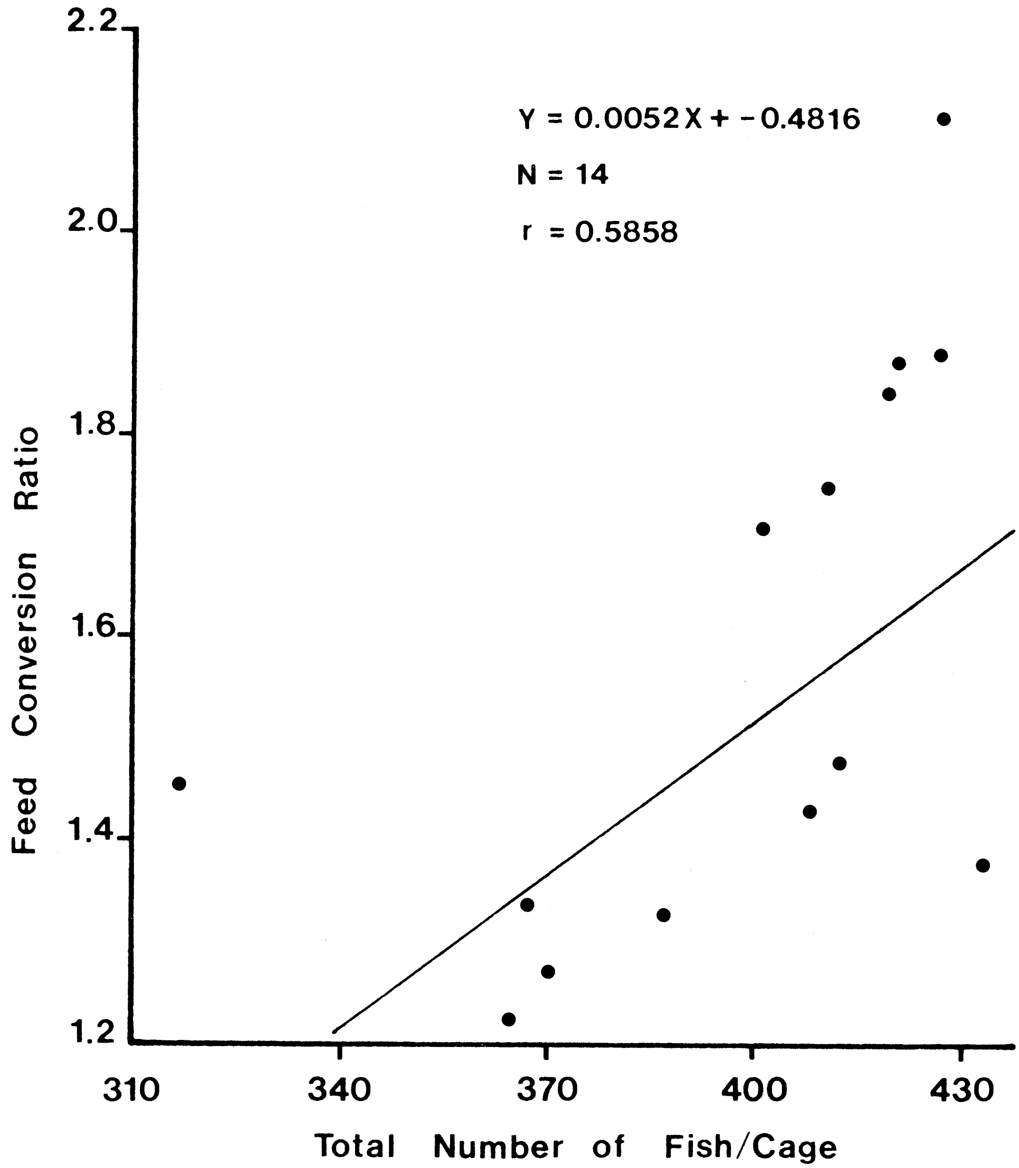
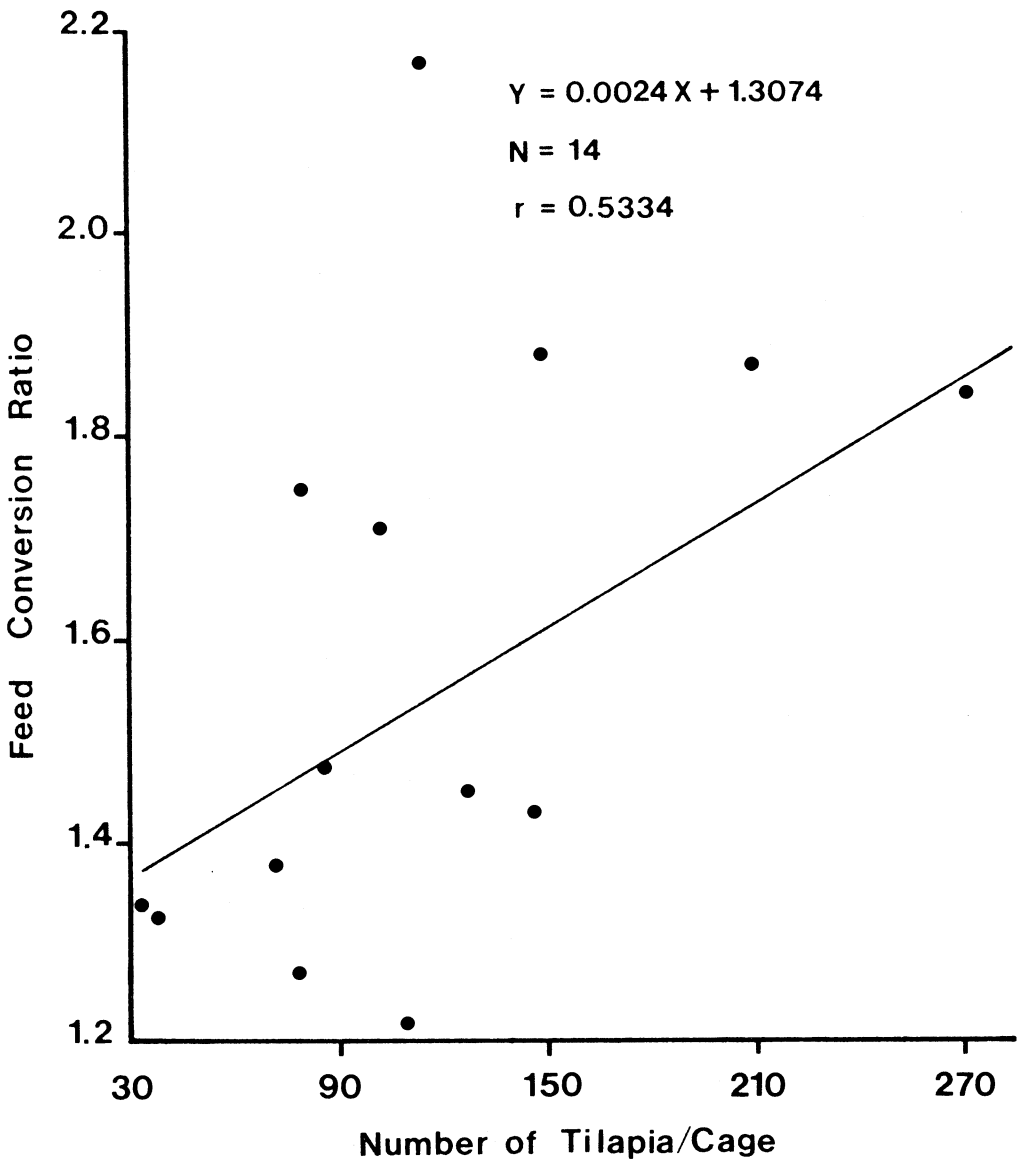

Y = 0.0052 X + -0.4816
N = 14
r = 0.5858
Feed Conversion Ratio
2.2
2.0
1.8
1.6
1.4
1.2
310
340
370
400
430
Total Number of Fish/Cage

Figure 5. Correlation between feed conversion ratio and the number of tilapia/cage.


Y = 0.0024 X + 1.3074
N = 14
r = 0.5334
2.2
2.0
1.8
1.6
1.4
1.2
Feed Conversion Ratio
30
90
150
210
270
Number of Tilapia/Cage

tilapia per cage and feed conversion efficiency was significant ($r = 0.533$, $P = 0.050$), whereas the correlation coefficient for channel catfish ($r = 0.245$), but not significant ($P = 0.399$).

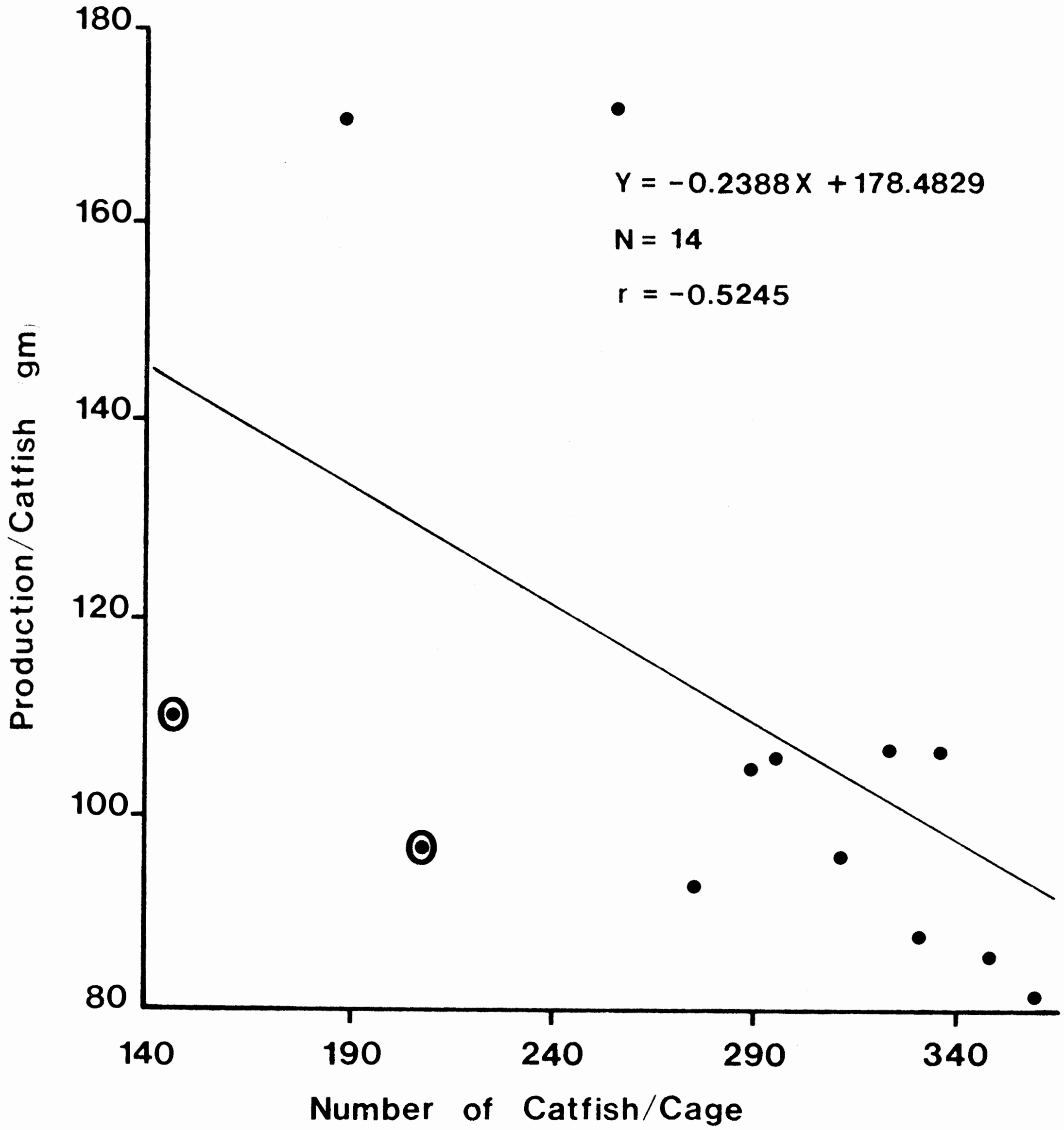
The number of catfish per cage was inversely correlated with the production of individual channel catfish ($r = -0.525$, $P = 0.054$), (Figure 6). The two abnormally low points on the figure (circled) represent two cages (3S and 4S) which contained the largest number of tilapia (Figure 6). There was not a significant correlation ($r = 0.159$, $P = 0.587$) between the number of tilapia per cage and the production per individual channel catfish, nor between the number of tilapia per cage and production per individual tilapia ($r = 0.227$, $P = 0.435$).

The average dissolved oxygen level was not related to total net production ($r = 0.068$, $P = 0.817$) even though dissolved oxygen reached critically low levels in some ponds near the end of the experiment. Dissolved oxygen was not correlated with feed conversion efficiencies ($r = -0.289$) ($P = 0.316$). However, feed conversion efficiency did tend to increase with decreasing dissolved oxygen levels.

Water Temperature

Water temperatures in the 0.4-ha ponds gradually rose from a low of 21.3 C on May 19 (Figure 7) to a high of 31.5 C on June 30. Morning temperatures of 30 C or greater were recorded from June 30 to July 28. Afternoon temperatures during this period reached 36 C 15 cm below the surface of the water. Consequently, feeding activity was severely reduced until water temperatures moderated. In August water temperature fluctuated between 26.1 C and 28.9 C (Tables 2 and 3) followed in September by abrupt cooling from 27.3 C in pond 2 on September 8, to

Figure 6. Correlation between production/catfish and the number of catfish/cage.



Y = −0.2388 X + 178.4829
N = 14
r = −0.5245
180
160
140
120
100
80
Production/Catfish (gm)
140
190
240
290
340
Number of Catfish/Cage

Figure 7. 1980 water temperatures in four 0.4-ha experimental ponds.

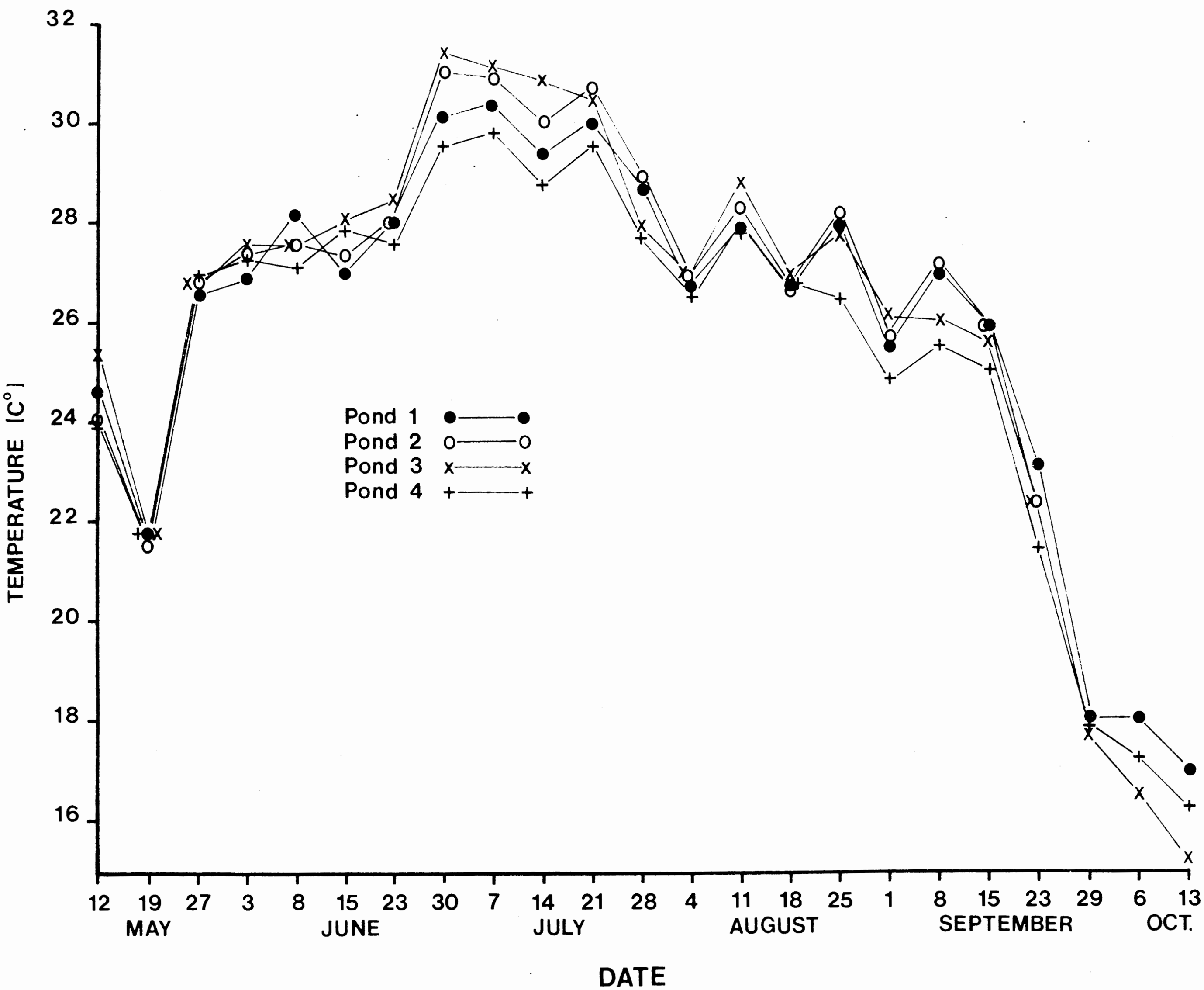

32
30
28
26
24
22
20
18
16
TEMPERATURE (C°)
Pond 1
Pond 2
Pond 3
Pond 4
12 19 27 3 8 15 23 30 7 14 21 28 4 11 18 25 1 8 15 23 29 6 13
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCT.
DATE

Table 2. Mean monthly temperatures for four 0.4-ha experimental ponds.

Pond no.	Month	Mean temperature C	Std. deviation	Range
1	May	24.4	2.5	21.7-26.6
	June	28.1	1.3	26.9-30.2
	July	29.7	0.8	28.8-30.5
	August	27.4	0.8	26.7-28.0
	September	24.0	3.6	18.1-27.1
	October	17.6	0.7	17.1-18.1
2	May	24.2	2.7	21.5-26.9
	June	28.3	1.6	27.4-31.2
	July	30.2	0.9	29.0-31.0
	August	27.6	0.8	26.8-28.4
	September	25.4	2.0	22.5-27.3
	October	-	-	-
3	May	24.6	2.6	21.7-26.7
	June	28.7	1.6	27.6-31.5
	July	30.2	1.5	28.0-31.2
	August	27.7	0.9	27.0-28.9
	September	23.6	3.6	17.8-26.2
	October	15.9	1.0	15.2-16.6
4	May	24.1	2.7	21.4-26.8
	June	27.9	1.0	27.1-29.6
	July	29.0	1.0	27.7-29.9
	August	27.0	0.7	26.6-28.0
	September	23.0	3.3	17.9-25.6
	October	16.8	0.7	16.3-17.3

Table 3. Mean monthly temperatures for three, 0.1-ha experimental ponds.

Pond no.	Month	Mean temperature C	Std. deviation	Range
6	May	26.1	0.1	26.0-26.2
	June	28.2	1.7	27.0-30.9
	July	30.3	0.9	29.3-31.0
	August	27.1	0.9	26.1-28.0
	September	23.0	3.7	17.9-26.2
	October	16.4	0.8	15.8-17.0
7	May	26.1	0.1	26.0-26.2
	June	28.2	1.9	26.8-31.2
	July	30.3	0.9	29.1-31.2
	August	27.1	0.8	26.1-27.9
	September	22.9	3.7	17.1-26.2
	October	16.1	0.8	15.5-16.7
9	May	24.9	2.5	22.2-27.1
	June	28.0	1.4	26.6-30.3
	July	29.3	0.8	28.4-30.0
	August	26.7	0.6	26.1-27.3
	September	22.8	3.5	17.2-26.0
	October	16.6	1.7	15.4-17.8

17.7 C on September 29. Water temperatures in the 0.1-ha ponds followed approximately the same pattern (Figure 8).

Mean water temperature throughout the growing season was similar in all ponds except pond 2. Mean temperature in pond 2 was approximately 2 C warmer than that in the other ponds (Table 4).

Dissolved Oxygen

Although mean dissolved oxygen concentration in the ponds over the entire growing season ranged from 4.70 mg/1 to 7.12 mg/1 (Table 5), there were periods, especially in August, when dissolved oxygen levels in some ponds dropped as low as 0.2 mg/1 (Tables 6 and 7). Dissolved oxygen concentration in three of the 0.4-ha ponds (ponds 1, 2, and 3) was highest in May at 10.9 mg/1 (Figure 9) and declined over the summer until a low point was reached in late August. By September the decline had ended and the trend was toward increasing dissolved oxygen values for the rest of the season. Pond 4 was consistently 1-2 mg/1 lower in dissolved oxygen than were ponds 1, 2, and 3. However, pond 4 also followed a pattern of decreasing dissolved oxygen values until late August. On September 1 and thereafter the trend was toward increasing dissolved oxygen concentrations in the water until the end of the season. The low dissolved oxygen period in pond 4 from August 18 to September 1 resulted in heavy mortality of channel catfish. Dissolved oxygen levels in this pond remained near or below 3 mg/1 from August 4 until October 6.

Dissolved oxygen levels in the 0.1-ha ponds follow the same pattern as that described for the 0.4-ha ponds. However, dissolved oxygen concentration remained somewhat higher until July 21 (Figure 10).

Figure 8. 1980 water temperatures in three 0.1-ha experimental ponds.

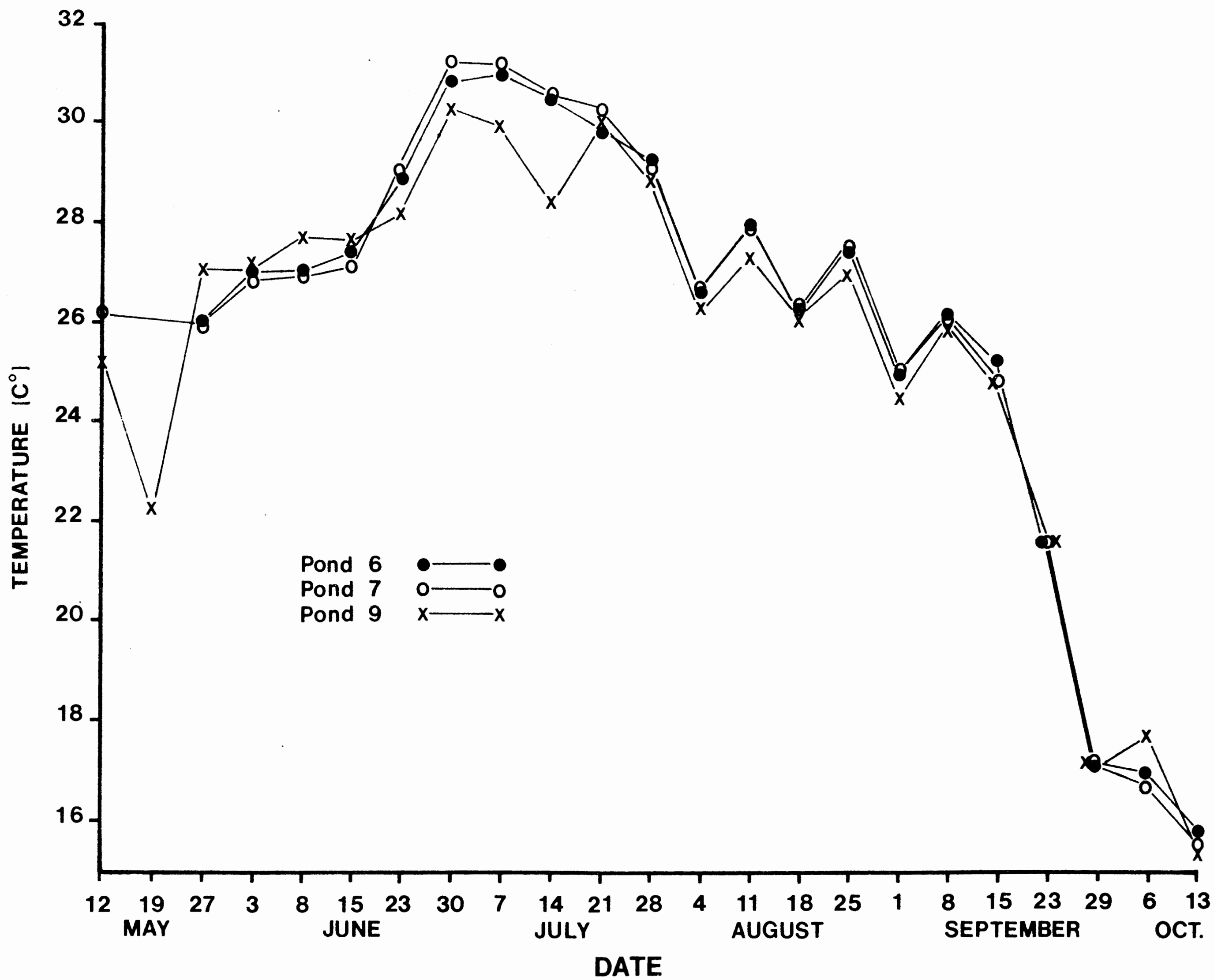

32
30
28
26
24
22
20
18
16
TEMPERATURE (C°)
Pond 6
Pond 7
Pond 9
12 19 27 3 8 15 23 30 7 14 21 28 4 11 18 25 1 8 15 23 29 6 13
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCT.
DATE

Table 4. Mean water temperature during the 1980 growing season.

Pond	(c) Temperature	Std. deviation	Range
1	25.2	4.3	17.1-30.5
2	27.1	2.4	21.5-31.2
3	25.1	5.2	15.2-31.2
4	24.6	4.5	16.3-29.0
6	25.2	4.9	15.8-31.0
7	25.1	5.0	15.5-31.2
9	24.7	4.6	15.4-30.3

Table 5. Mean dissolved oxygen concentrations during the 1980 growing season.

Pond	Mean (mg/1) dissolved oxygen	Std. deviation	Range
1	7.12	1.88	2.50-10.90
2	6.06	1.68	3.30-9.23
3	6.42	2.52	2.63-10.66
4	4.70	3.10	0.20-10.30
6	5.88	2.14	1.63-10.50
7	5.87	1.90	1.43-9.67
9	5.10	2.45	1.27-10.13

Table 6. Mean monthly dissolved oxygen concentrations for four, 0.4-ha experimental ponds.

Pond no.	Month	Mean (mg/1) dissolved oxygen	Std. deviation	Range
1	May	9.49	1.23	8.65-10.90
	June	8.75	0.54	8.27-9.60
	July	7.25	0.53	6.50-7.76
	August	5.52	0.97	4.23-6.57
	September	4.51	1.20	2.50-5.60
	October	7.20	0.00	7.20-7.20
2	May	7.06	0.22	6.86-7.30
	June	7.98	0.70	7.60-9.23
	July	6.66	0.88	6.03-7.90
	August	4.13	0.65	3.30-4.73
	September	4.48	0.64	3.90-5.33
	October	-	-	-
3	May	9.82	0.79	9.10-10.66
	June	8.23	1.00	7.13-9.27
	July	7.84	0.53	7.13-8.40
	August	4.18	1.06	2.63-5.03
	September	4.68	1.87	3.60-6.70
	October	3.79	0.69	3.30-4.27
4	May	10.07	0.32	9.70-10.30
	June	5.37	1.05	4.06-6.50
	July	4.11	1.61	2.20-5.73
	August	1.46	1.19	0.43-2.90
	September	1.96	1.34	0.20-3.40
	October	5.24	0.23	5.07-5.40

Table 7. Mean monthly dissolved oxygen concentrations for three, 0.1-ha experimental ponds.

Pond no.	Month	Mean (mg/1) dissolved oxygen	Std. deviation	Range
6	May	8.20	2.40	6.50-9.90
	June	7.38	2.51	3.90-10.50
	July	7.12	2.05	4.83-8.80
	August	3.91	1.80	2.00-6.33
	September	2.75	1.39	1.63-4.77
	October	5.90	0.89	5.27-6.53
7	May	7.79	1.86	6.47-9.10
	June	7.15	1.74	5.10-9.67
	July	7.24	2.32	4.47-9.63
	August	3.32	2.22	1.43-6.37
	September	3.77	1.28	2.70-5.90
	October	5.97	0.23	5.80-6.13
9	May	7.92	0.81	7.00-8.50
	June	7.68	1.95	5.40-10.13
	July	5.68	0.28	5.27-5.87
	August	2.74	1.27	1.57-4.43
	September	2.09	0.74	1.27-3.23
	October	4.47	0.28	4.27-4.67

Figure 9. 1980 dissolved oxygen values for four 0.4-ha experimental ponds.

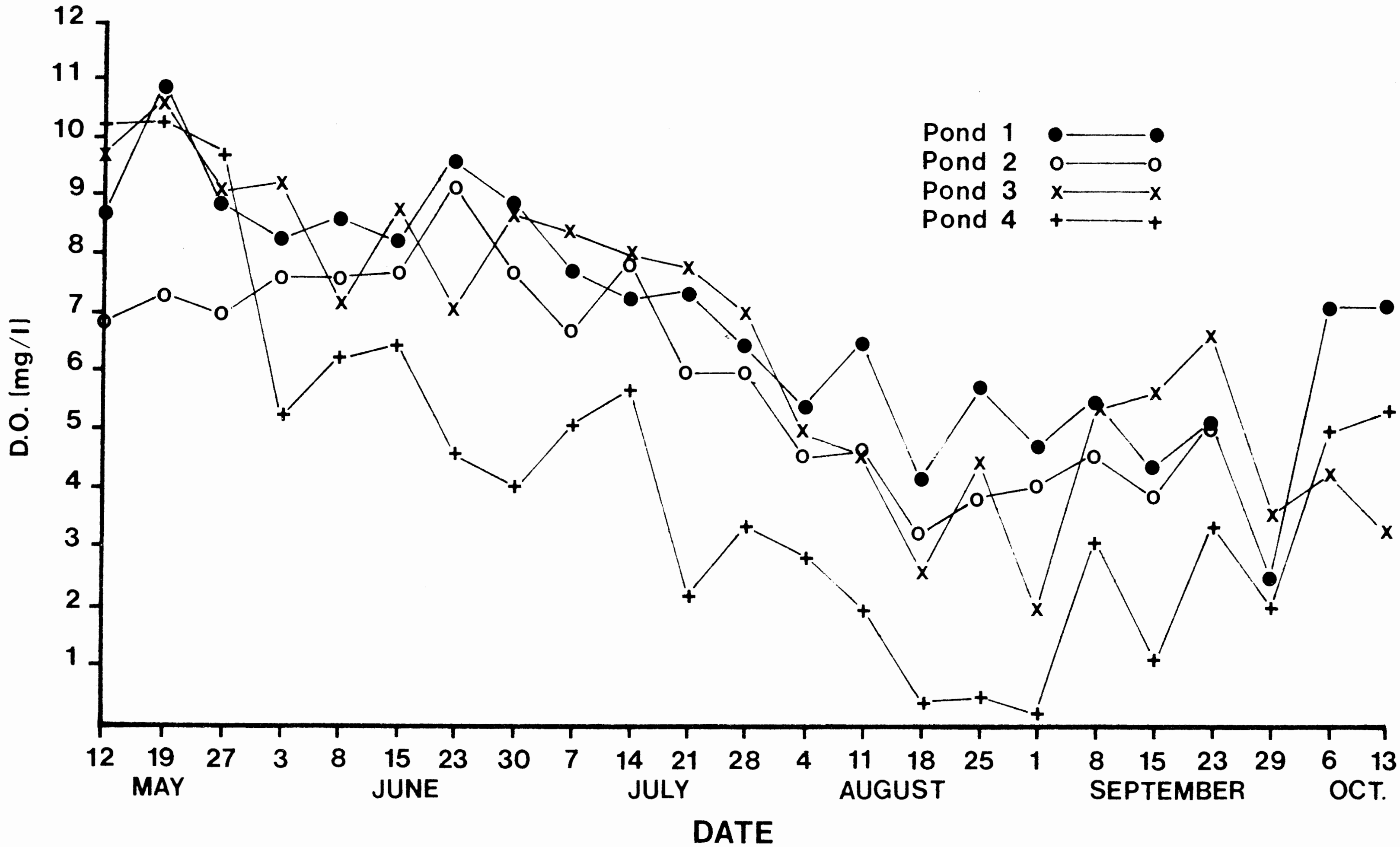
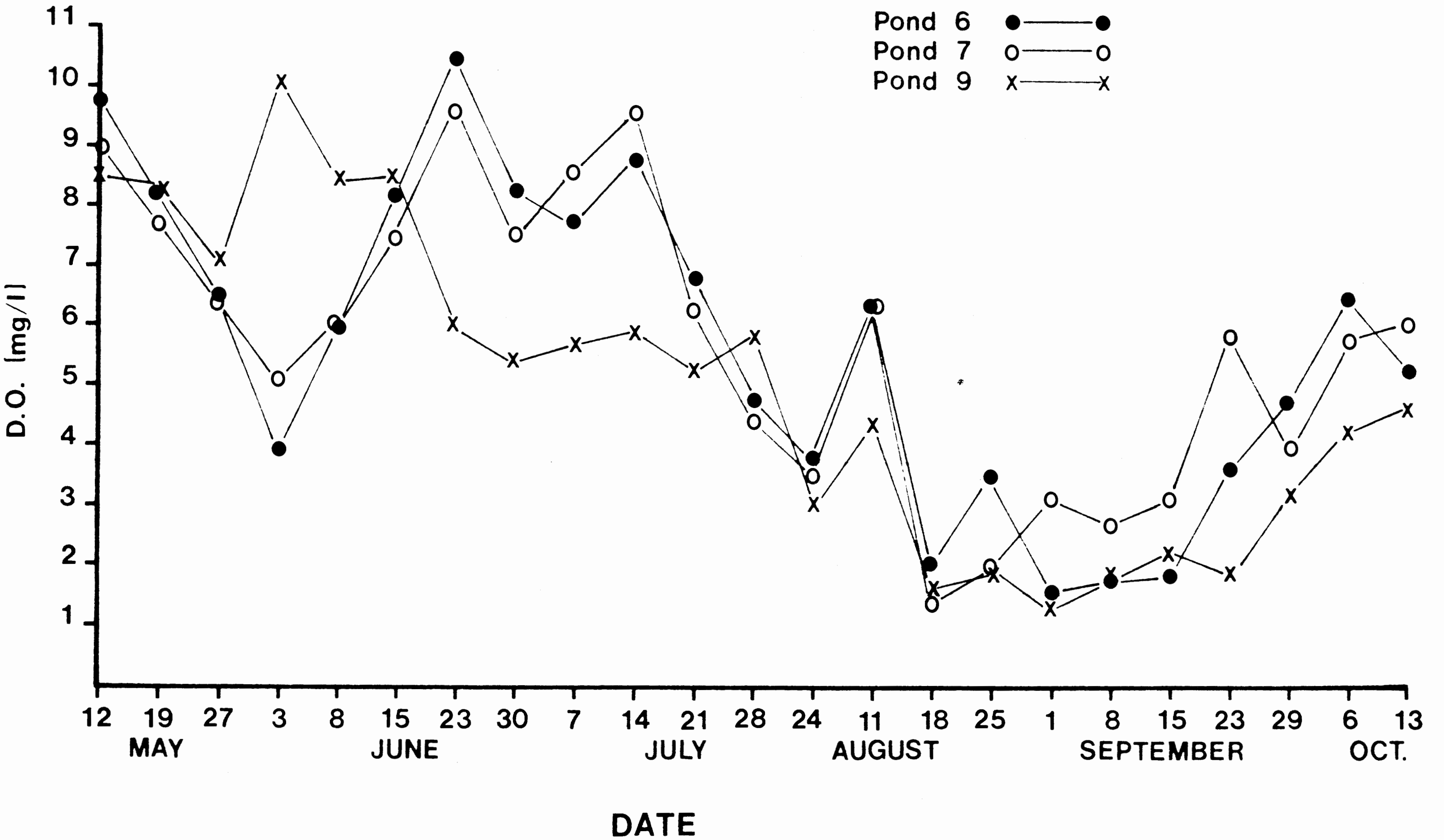

Pond 1
Pond 2
Pond 3
Pond 4
D.O. (mg/l)
12
11
10
9
8
7
6
5
4
3
2
1
12 19 27 3 8 15 23 30 7 14 21 28 4 11 18 25 1 8 15 23 29 6 13
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCT.
DATE

Figure 10. 1980 dissolved oxygen values for three 0.1-ha experimental ponds.



Pond 6
Pond 7
Pond 9
D.O. (mg/l)
11
10
9
8
7
6
5
4
3
2
1
12
19
27
3
8
15
23
30
7
14
21
28
24
11
18
25
1
8
15
23
29
6
13
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCT.
DATE

At this time the dissolved oxygen level began to decline until August 18, and from that date until September 23 it remained near or above 3 mg/1.

Discussion

No significant correlations were found among the treatments. However, unusual climatic conditions in the summer of 1980 precluded rigorous analysis. During this period both air temperatures and consequently water temperatures were much above normal for an extended period of time. Air temperatures near or above 38 C were common from mid-June until mid-August, while mean morning water temperatures (Figures 7 and 8) of 30 C or greater (an average value derived from surface, 0.5-m and 1.0-m readings) were recorded from June 30 until July 28. Afternoon surface temperatures reached 36 C. These temperatures greatly reduced the amount of feed consumed by the channel catfish (Neff and Barrett 1975) and to a lesser extent the tilapia (Gleastine 1974). Allen and Strawn (1968) found that channel catfish acclimated at 30 C had an incipient upper-lethal temperature of 37.3 C. The incipient lethal temperature was very near the temperatures experienced in the ponds over the four-week mid-summer period. Also the higher temperatures may indirectly cause mortality over a still longer period of time by increasing the rate of metabolism beyond the fish's abilities to consume food. This situation is known to occur in channel catfish at temperatures above approximately 36 C (Allen and Strawn 1968). Fortunately, thermal stratification resulted in as much as 2.5 C lower temperatures in the bottom of the cage. This stratification alleviated heat stress at times and probably prevented high mortality among channel catfish.

Aquatic vegetation was another factor that influenced the results of cage culture in 1980. Vegetation in the experimental ponds filled the entire water column throughout the growing season. These aquatic macrophytes buffered wind and wave action (Rottman 1977) which would mix the water, increase dissolved oxygen and dilute accumulated wastes. However, the heavy growth of submersed vegetation also allowed temperature and dissolved oxygen stratification to persist throughout much of the growing season. Persistent stratification further reduced mixing of the water. An electric trolling motor was employed to break the stratification. However, mixing occurred for short periods but never lasted more than a few hours after the motor was turned off. At times dissolved oxygen stratification in pond 4 resulted in 0.1 mg/1 oxygen concentration at depths below 0.5 m, while surface values were 5.7 mg/1. This oxygen differential proved important because channel catfish, a naturally bottom dwelling species, often remained at the bottom of the cage even though dissolved oxygen was considerably higher near the surface. Water quality problems resulted in mean weights of channel catfish approximately 200-250 g less than those attained the following year in the same ponds at similar densities.

Tilapia were initially stocked at weights ranging from 120-199 g and showed net gains of 6 g (cage 1M) to 150 g (cage 7) per tilapia (Table 1). In 1981 net gains were 264 g per tilapia. The poor weight gains exhibited by tilapia were caused not only by environmental stress but also by the poor condition of the fish when stocked. K factor for 1980 was 1.76 as compared with 2.76 the following year for fish of similar length.

Percent mortality of both species was initially high at stocking but continued at a reduced rate the entire growing season. High mortality changed channel catfish-tilapia ratios and total fish densities to the extent that replicates were no longer comparable, thus results from the cages were analyzed using linear regression to determine the presence of significant trends.

A significant inverse relationship (P = 0.005) was found to exist between the total number of fish per cage and individual channel catfish production. Individual channel catfish production decreased as the total number of fish per cage increased. These results are similar to the results obtained by Pennington and Strawn (1978) (Figure 2). However, contrary to the results of these authors, total net production of channel catfish tended to decrease as total numbers of fish increased (Figure 3). This decrease was statistically significant (P = 0.086), and may be due to competitive feeding inhibition of the smaller channel catfish by the tilapia in the case of cages containing high proportions of tilapia. This possibility has been suggested by Dunseth and Smitherman (1977) who pointed out the need to stock the two species at comparable sizes. Another possibility is that low dissolved oxygen exerted a greater negative influence in the higher density cages. Low dissolved oxygen coupled with increased respiration by the fish or greater concentrations of waste products such as ammonia (NH_3-N, NH_4+) could limit production (Robinette 1976). A combination of these factors is the most probable explanation of decreased net production of channel catfish. This conclusion is supported by the findings of Andrews et al. (1971) who showed that water quality and not density of fish was the major growth limiting factor for channel catfish.

In contrast to the relationship between numbers and production of channel catfish, there was no correlation between individual or total net tilapia production and numbers of fish per cage. This reversal of the previous data seems reasonable as tilapia are more tolerant of adverse water quality conditions (Stickney and Hesby 1978) than are the channel catfish. Tilapia production appeared to be more closely related to the health and physical condition of the fish at stocking than to any other factor.

A significant positive correlation (P = 0.028) was found between total number of fish and feed conversion efficiency (Figure 4). This result could have been caused by increasing numbers of tilapia at the higher densities. The tilapia, because of size and physical condition, were thought to have higher feed conversion efficiencies than the channel catfish and therefore larger ratios of tilapia to channel catfish would tend to increase the feed conversion efficiency for the cage. This relationship is further evidenced by the high positive correlation (P = 0.050) between the number of tilapia per cage and the feed conversion efficiency (Figure 5). The poorer feed conversion efficiency of the tilapia as compared to typical values of 0.92-1.56 (Allison et al. 1976) was due to the impaired health of the fish and to the fact that it was necessary to initially stock large fish (120-199 g). These tilapia had reached a plateau in the growth curve (100-120 g) where growth per unit of food begins to decrease and thus food conversion efficiency becomes greater (Bowman 1977).

Graphic analysis revealed an inverse correlation between channel catfish production and the number of channel catfish per cage (P = 0.539) (Figure 6). Again, marginal water quality conditions, low dissolved oxygen concentrations, high temperatures and possibly, density dependent toxic waste products were likely responsible for this relationship. In other studies (Schmittou 1970; Kilambi et al. 1977; and Pennington and Strawn 1978) net production continued to increase to a stocking density of 900 channel catfish per m^3, although individual production of the channel catfish did decline.

There was no significant correlation between number of tilapia per cage and production per channel catfish and none between number of tilapia per cage and production per tilapia. Poor water quality and poor health of the tilapia probably masked any possible effects of the experimental stocking ratios.

Dissolved oxygen concentration was not significantly correlated with total net production. However, dissolved oxygen limitations contributed to the lack of acceptable growth of the channel catfish. Stickney (1979) and Andrews et al. (1973) have stated that growth is reduced when dissolved oxygen drops below saturation (approximately 7.5 mg/1) and growth is significantly reduced at values below 5 mg/1. After July 28 dissolved oxygen also declined to levels that have been reported to significantly reduce growth. Therefore low dissolved oxygen may have had the greatest impact on growth from the beginning of August (Figure 9) until harvest.

The late summer dissolved oxygen decline was precipitated by several factors: (1) decaying aquatic vegetation which increased Biological Oxygen Demand; (2) accumulated waste products that resulted in a possibly large Chemical Oxygen Demand; and, (3) intermittemt cloudy weather that began in August. The clouds blocked the sun and reduced phytoplankton and macrophytic photosynthesis, reducing oxygen production (Odum 1971).

These three factors that reduced oxygen levels were to a small degree offset by: (1) declining water temperatures that increase the saturation level of oxygen; (2) reduced densities of aquatic macrophytes, allowing more water circulation; and, (3) increasing winds which aid the mixing of water and the diffusion of oxygen into the water from the air. However, these factors were not sufficient to counterbalance the decrease in dissolved oxygen concentration.

Wilson and Hilton (1981) indicate that for optimum growth of channel catfish, tilapia should comprise no more than 25 percent of a channel catfish-tilapia polyculture. Although this conclusion was not strongly indicated by our data, small stocking ratios of tilapia to channel catfish may in fact be desirable for cage polyculture for the following reasons: First, due to aggressive behavior (Wilson and Hilton; Dunseth and Smitherman 1977), large numbers of tilapia increase the possibility of deleterious competitive interactions with channel catfish whereas smaller numbers of aggressively feeding tilapia may stimulate channel catfish to feed more vigorously and thus increase production. Second, the channel catfish has proven wide consumer acceptance and marketability whereas the tilapia is not well known to the general public. Therefore financial risk may be reduced by using the channel catfish as the major constituent of the polyculture.

CHAPTER II

POLYCULTURE OF THREE SELECTED RATIOS OF CHANNEL CATFISH AND TILAPIA *AUREA* IN SMALL PONDS

Introduction

The small properly managed farm pond has the potential for producing large quantities of high quality fish protein. However, in Oklahoma most of these ponds cannot be efficiently drained or seined (Toetz 1978) and thus traditional methods of open water fish culture are not possible. Cage culture appears to be one method of overcoming these limitations for pond owners to produce fish for home consumption or as a supplemental cash crop.

Most cage culture has been conducted with channel catfish (*Ictalurus punctatus*), or blue tilapia (*Tilapia aurea*) (Schmittou 1970; Lovell 1972; Kilambi et al. 1977; Collins 1978; Pennington and Strawn 1978; Newton 1980) and little research has been directed toward potential polyculture of the two species. It is toward this evaluation that this study is directed.

Bardach et al. (1972) state that where tilapia were added to existing fish culture systems, total production increased with no reduction in production in the non-tilapia elements. Their conclusion seems to be true also for catfish grown in polyculture with tilapia. Perry and

Avault (1972) obtained greater total production from ponds stocked only with free swimming channel catfish. Clady (1981) found that *T. aurea* seemed to stimulate production of pen raised channel catfish, and Maughan et al. (1981) observed a similar effect in cages. One explanation is that tilapia consume waste feeds (Williamson and Smitherman 1975), and their natural planktivorous feeding habits contribute additional production (Armbrester 1972). These studies point to the possibility that polyculture of caged channel catfish-*T. aurea* may offer the small pond owner a method of increasing production.

The primary objectives of this experiment were to: (1) determine if polyculture in small shallow ponds could produce marketable-sized channel catfish from small (23 g) fingerlings in one comparatively short growing season; (2) ascertain whether small numbers of *T. aurea* could increase net production in caged channel catfish; and, (3) document any differences in mean weight of channel catfish and the percent harvestable fish produced in polyculture versus monoculture.

Methods and Materials

The experiment was conducted at the Oklahoma State University experimental pond facility located 12 km west of Stillwater, Oklahoma, and at a private pond located 12 km southwest of Stillwater. The 1-m^3 cages were suspended from docks in approximately 2 m of water in the 0.4-ha experimental ponds and anchored in 4 m of water in the private 4-ha pond.

Average weight at stocking was approximately 23 g for channel catfish and 45 g for *T. aurea*. The fish were stocked between May 14 and May 22 when water temperature was 20 C. Feeding began May 23 and ended October 5. The fish were fed a 32 percent protein, nutritionally complete, floating, pelleted feed. They were generally fed daily all that they could consume in a 20-30 minute period. Weekly mid-morning dissolved oxygen and water temperature measurements were taken at the surface, middle, and bottom of each cage, and a mean value was calculated. At harvest, a random sample of 50 channel catfish and all *T. aurea* from each cage were individually weighed and measured, and the remaining channel catfish were batch weighed.

A separate study was carried out in a 0.4-ha stock pond to determine if possible differences in mean weight of channel catfish among the three treatments could be caused by density of channel catfish. In this study three cages were stocked at densities of 350, 400 and 450 channel catfish, respectively. The fish were then treated the same as the fish in the polyculture experiment.

Results

Channel catfish consistently exhibited superior individual weight gains in the treatment containing 50 *T. aurea* and 350 channel catfish ($P = 0.0971$). Channel catfish in cages containing 0 *T. aurea* had a mean weight of 300.7 g, those in cages with 10 *T. aurea* had a mean weight of 313.1 g and those in cages with 50 *T. aurea* had a mean weight 353.6 g (Table 8). Mean weights for *T. aurea* in the cages where 10 and 50 tilapia were stocked were not significantly different, averaging 307.1 and 308.0 g respectively (Table 9).

Percent harvestable channel catfish (340 g or greater) ranged from a low of 35 percent (140 fish) in those cages stocked with no tilapia, 39 percent (152 fish) in cages stocked with 10 tilapia and

Table 8. Production per cage of three densities of tilapia-channel catfish grown in polyculture.

Parameter	400 Catfish 0 Tilapia	390 Catfish 10 Tilapia	350 Catfish 50 Tilapia
Mean wt/catfish (g)	300.7	313.1	353.6
Total net prod. (kg)	112.3	112.5	122.6
Net prod. of catfish (kg)	112.3	110.1	110.3
Total % harvestable fish	35.0	39.8	53.4
% harvestable catfish	35.0	39.0	49.5
K factor catfish	1.22	1.17	1.20
Coefficient of variation	0.43	0.38	0.38
Conversion efficiency	1.81	1.88	1.83

Table 9. Production per cage of tilapia at three densities of tilapia-channel catfish grown in polyculture.

Parameter	350 Catfish 10 Tilapia	350 Catfish 50 Tilapia
Mean weight/tilapia (g)	307.1	308.0
Net production of tilapia (kg)	2.40	12.26
% harvestable tilapia	75.4	81.9
K factor tilapia	2.36	2.40
Coefficient of variation	.28	.29

reached a maximum of 50 percent (175 fish) in those cages stocked with 50 tilapia. Percent harvestable channel catfish in these treatments were significantly different at the P = 0.1031 level. Percent harvestable *T. aurea* (227 g or greater) was 76 percent in cages stocked with 10 *T. aurea* and 82 percent for those stocked with 50 *T. aurea*. These treatments were not significantly different in the percent harvestable tilapia. The total mean percent harvestable fish including both species was 35 percent (140 fish) for cages containing no tilaipa, 40 percent (159 fish) for those containing 10 tilapia and 53 percent (214 fish) for cages containing 50 tilapia. These treatments were significantly different at the P = 0.019 level in the amount of harvestable fish.

Total net production and mean net production of catfish per cage were not significantly different among treatments. However, mean total net production per cage did differ slightly. Cages containing no tilapia produced 112.32 kg of fish flesh, those containing 10 tilapia produced 112.50 kg of fish flesh and those containing 50 tilapia produced 122.57 kg of fish flesh (Table 8). There were no significant differences among treatments for either species in feed conversion efficiencies, coefficients of variation for mean weights of fish (CV = $SD/\overline{X}$), or K factor. There was no evidence that differential density of channel catfish at the densities tested had any effect upon the growth characteristics of individual fish (mean weights per fish were 144.3 g at a density of 350 channel catfish per m^3, 152.0 g at a density of 400 channel catfish per m^3, and 148.6 g at a density of 450 channel catfish per m^3 from a pond used to test this range of densities). In addition, there was no consistent relationship between the water chemistry of the ponds and individual growth characteristics of either species. Mean dissolved oxygen concentrations in the experimental ponds ranged from 4.63 mg/1 to 5.88 mg/1; in the larger pond it was 6.85 mg/1, and in the channel catfish density pond it was 3.56 mg/1.

Discussion

This experiment indicates that increases in mean weight of channel catfish of approximately 53 g and a corresponding 18.4 percent increase in the number of harvestable fish can result from the introduction of small numbers of *T. aurea* into cages containing channel catfish. The cages containing 50 *T. aurea* and 350 channel catfish also showed increased net production by approximately 10 kg per cage over the cages containing 400 channel catfish but increased production was accompanied by increased feed consumption of 9.6 percent. These production increases are especially meaningful to the small-scale aquaculturist contending with comparatively short growing seasons or the necessity of using bodies of water of marginal quality.

Although competition between channel catfish and tilapia has been reported by Dunseth and Smitherman (1977), no evidence of competition was found in this study. The mean weight coefficient of variation per channel catfish was not significantly different among treatments or between stocked and harvested fish (.38-.43) and weight frequency distributions were approximately normal. These values were also similar to those reported as typical (.30-.40) by Konikoff and Lewis (1974), and suggest that *T. aurea* did not affect weight frequency distribution of the channel catfish. This consideration is important because even though mean weights of channel catfish growth with *T. aurea* were greater than those grown without tilapia, a bimodal or skewed weight frequency distribution or large coefficient of variation could have indicated adverse interactions.

Feed conversion efficiencies among treatments ranged from 1.81 in cages with no *T. aurea* to 1.88 in cages with 10 *T. aurea*. This lack of significant differences in feed conversion efficiencies again indicates that the tilapia had little effect on the conversion efficiencies of the channel catfish. Lack of negative interactions is even further evidenced by the absence of significant differences between the K factors of channel catfish cultures along and those of catfish cultured with tilapia.

The increased production occurring in the cages containing 50 tilapia may be the result of a response of the channel catfish to the aggressive feeding pattern of *T. aurea*. In addition, since tilapia normally feed over a wider range of temperature and dissolved oxygen conditions than channel catfish, this stimulus may initiate channel catfish feeding even during sub-optimal conditions. Thus, the aggressive feeding of *T. aurea* may stimulate channel catfish to feed more vigorously during optimal and especially during sub-optimal temperature and dissolved oxygen conditions, which may result in increased production in the polyculture cages.

CHAPTER III

PARTIAL BUDGET ANALYSIS OF CHANNEL CATFISH-TILAPIA CAGE CULTURE IN SMALL PONDS

The economics of small-scale fish culture may be viewed from three different perspectives: (1) raising fish and selling them to a processor at a live weight wholesale price; (2) selling the fish to the consumer from the pond bank at a retail price; or (3) using fish for home consumption.

Table 10 represents a partial budget based on total production from four, 1-m^3 cages containing 350 channel catfish and 50 tilapia in a 0.4-ha pond. This budget was prepared from the viewpoint of selling to a processor at current (March 1982) prices. The budget is partial in that it assumes the pond has been previously constructed and has no maintenance cost; in addition, the budget does not include transport, marketing costs, or interest rates. A feed conversion efficiency of 1.80 was assumed as was 5 percent mortality of fish. A provision is made in the budget to demonstrate total return from the cages and the return based on 53 percent harvestable fish (340 g or greater) in the first growing season. This value is derived from data obtained in 1981 on percent harvestability of channel catfish grown in cages in small ponds. The minimum acceptable weight of most fish processors is 340 g or greater. Fish that do not attain the mimimum

Table 10. Partial wholesale budget based on total production of four 1-m^3 cages containing 350 channel catfish-50 tilapia in a 0.4-ha pond.*

Production:	
125kg/cage x 4 cages = 500kg - 5 % mortality = 475kg	
475kg @ $2.09/kg = a return of	$992.75
Fluctuating production expenses:	
channel catfish fingerlings 1400 @ $0.15/fish	$210.00
tilapia fingerlings 200 @ $0.15/fish	$ 30.00
fish feed approximately 1000kg @ $0.42/kg	$420.00
Annual fixed costs:	
cages (4) @ approximately $45.00/cage amortized over 5 years.	$ 36.00
cage maintenance (wire, styrofoam) misc. equipment	$ 20.00
Total production costs:	$716.00
Gross Returns to labor and management:	$276.75
Labor:	
fingerling transport 8 hrs. @ $3.00/hour.	$ 24.00
stocking fingerlings 8 hrs. @ $3.00/hour.	$ 24.00
feeding 136 days @ 0.5 hours/day @ $3.00/hour.	$204.00
harvesting fish 8 hours @ $3.00/hour.	$ 24.00
Return to labor:	$276.00
Return to management:	$ 0.75

Assumptions:

All fish are marketable.

Conversion efficiency is 1.80.

Cost of transportation to market is not included.

*This budget can only be used as a generalization of actual dollar amounts due to fluctuating market, feed, fingerling, and equipment prices.

weight the first year may be held over and sold the following June or July, a period when premium prices may be obtained for harvestable channel catfish.

The greatest expense in cage culture is feed cost. A nutritionally complete ration (Robinette 1977) purchased at a current price of \$0.42 per kg costs \$420.00 per 1000 kg. Fingerlings are the second largest investment at a total price of \$240.00 The four cages cost approximately \$45.00 each (for a complete description of cage construction and expense see appendix D). Amortized over the minimum life expectancy of a cage of 5 years, the annual cost is \$36.00. The maintenance and miscellaneous equipment category includes the cost of a small boat depreciated over its 20 year life span and costs of dip net, rope and cage repair material. Labor costs can only be approximations because every individual situation is different. The time involved in the various labors reflect my own experience. The wholesale price of \$2.09 per kg live weight paid to the producer is an average obtained by calling several state processors and asking for current price quotes. These prices ranged from \$1.87/kg to \$2.42/kg. Fish production of 125 kg/cage is an average based on data collected in 1981. Total harvested weight per cage ranged from 104.397 kg to 140.516 kg. It can easily be seen from this budget that cage culture in one 0.4-ha, 100 percent harvested pond is not highly profitable to management; the return is \$0.75 on an investment of \$716.00. This minimal profit becomes a loss when the more realistic value of 53 percent harvestability is used. From this vantage point management and labor lose \$189.32 on the investment and management alone loses \$465.32 if labor costs are paid. Although it should be remembered that better production is possible, obviously a different approach must be taken (Table 11).

One method might be retail sales from the pond bank (Table 12). The present retail price of fish sold on the pond bank is $3.30/kg live weight (quoted from a regional Oklahoma channel catfish producer). An additional $0.55/kg can be charged for dressing the fish. These factors lead to a total retail sale price of $3.85/kg of fish. Costs of production remain the same as for the previous case except for labor. To offset labor differences an additional 40 hours labor at $3.00/hr. for a total of $120.00 has been added for time spent dealing with customers. Another 30 hours at $3.00/hr. for a total of $90.00 has been added for processing the fish. This marketing method increases the labor costs by $210.00. However, the retail selling price more than covers the labor charges and allows a return to management of $455.50 to $626.75 on total fish production. Assuming 53 percent harvestable fish, as before, returns are considerably reduced (Table 13). In this situation cost of labor is lowered somewhat, but management loses $265.40 by selling retail from the pond or $126.80 by selling retail dressed live weight from the pond. Profits may be recouped the following summer when the remaining small fish reach harvestable weight. However, this dual-year marketing approach requires that the initial capital be invested for approximately 15 months as compared with 7 or 8 months for an annual marketing program.

A third method of estimating the economic value of small-scale caged fish culture is to compare it with that of the family garden. In this situation the fish are grown primarily for home consumption. Disregarding the producer's labor, the fish can be grown for $1.50/kg; a savings of $2.35/kg over the already quoted pond bank dress out

Table 11. Partial wholesale budget based on 53 percent of total fish production harvestable from four, 1-m^3 cages containing 350 channel catfish-50 tilapia in a 0.4-ha pond.*

Production:	
63kg/cage x 4 cages = 252kg @ $2.09/kg =	$526.68
Fluctuating production expenses:	
channel catfish fingerlings 1400 @ $0.15/fish	$210.00
tilapia fingerlings 200 @ $0.15/fish	$ 30.00
fish feed approximately 1000kg @ $0.42/kg	$420.00
Annual fixed costs:	
cages (4) @ approximately $45.00/cage amortized over 5 years.	$ 36.00
cage maintenance (wire, styrofoam) misc. equipment	$ 20.00
Total production costs:	$716.00
Gross returns to labor and management:	-$189.32
Labor:	
fingerling transport 8 hrs. @ $3.00/hour.	$ 24.00
stocking fingerlings 8 hrs. @ $3.00/hour.	$ 24.00
feeding 136 days @ 0.5 hours/day @ $3.00/hour.	$204.00
harvesting fish 8 hours @ $3.00/hour.	$ 24.00
Return to labor:	$276.00
Return to management:	-$465.32

Assumptions:

Conversion efficiency is 1.80.

Cost of transportation to market is not included.

*This budget can only be used as a generalization of actual dollar amounts due to fluctuating market, feed, fingerling and equipment prices.

Table 12. Partial retail budget based on total production of four 1-m^3 cages containing 350 channel catfish-50 tilapia in a 0.4-ha pond.*

Production:		
125kg/cage x 4 cages = 500kg - 5% mortality = 475kg	live wt.	dressed
475 kg @ $3.30/kg live weight = a return of	$1567.50	
or 475kg @ $3.85/kg dressed = a return of		$1828.75
Fluctuating production expenses:		
channel catfish fingerlings 1400 @ $0.15/fish	$ 210.00	$ 210.00
tilapia fingerlings 200 @ $0.15/fish	$ 30.00	$ 30.00
fish feed approximately 1000kg @ $0.42/kg	$ 420.00	$ 420.00
Annual fixed costs:		
cages (4) @ approximately $45.00/cage amortized over 5 years.	$ 36.00	$ 36.00
cage maintenance (wire, styrofoam) misc. equipment.	$ 20.00	$ 20.00
Total production costs:	$ 716.00	$ 716.00
Gross returns to labor and management:	$ 851.50	$1112.75
Labor:		
fingerling transport 8 hours @ $3.00/hour.	$ 24.00	$ 24.00
stocking fingerlings 8 hours @ $3.00/hour.	$ 24.00	$ 24.00
feeding 136 days @ 0.5 hour/day @ $3.00/hour	$ 204.00	$ 204.00
harvesting fish 8 hours @ $3.00/hour.	$ 24.00	$ 24.00
selling fish to consumers 40 hours @ $3.00/hour	$ 120.00	$ 120.00
dressing fish 30 hours @ $3.00/hour.	x	$ 90.00
Return to labor:	$ 396.00	$ 486.00
Return to management:	$ 455.50	$ 626.75

Assumptions:

Conversion efficiency is 1.80.

All fish are marketable.

*This budget can only be used as a generalization of actual dollar amounts due to fluctuating market, feed, fingerling, and equipment prices.

Table 13. Partial retail budget based on 53 percent of total fish production harvestable from four, 1-m^3 cages containing 350 channel catfish-50 tilapia in a 0.4-ha pond.*

Production:		
63kg/cage x 4 cages = 252kg @ $3.30/kg	live wt.	dressed
live weight or $3.85/kg dressed	$831.60	$970.20
Fluctuating production expenses:		
channel catfish fingerlings 1400 @ $0.15/fish	$210.00	$210.00
tilapia fingerlings 200 @ $0.15/fish	$ 30.00	$ 30.00
fish feed approximately 1000kg @ $0.42/kg	$420.00	$420.00
Annual fixed costs:		
cages (4) @ approximately $45.00/cage amortized over 5 years.	$ 36.00	$ 36.00
cage maintenance (wire, styrofoam) misc. equipment.	$ 20.00	$ 20.00
Total production costs:	$716.00	$716.00
Gross returns to labor and management:	$115.60	$254.20
Labor:		
fingerling transport 8 hours @ $3.00/hour.	$ 24.00	$ 24.00
stocking fingerlings 8 hours @ $3.00/hour	$ 24.00	$ 24.00
feeding 136 days @ 0.5 hour/day @ $3.00/hour.	$204.00	$204.00
harvesting fish 8 hours @ $3.00/hour.	$ 24.00	$ 24.00
selling fish to consumers 40 hours @ $3.00/hr.	$120.00	$120.00
dressing fish 30 hours @ $3.00/hour.	x	$ 90.00
Return to labor:	$396.00	$486.00
Return to management:	-$280.40	-$231.80

Assumptions:

Conversion efficiency is 1.80.

*This budget can only be used as a generalization of actual dollar amounts due to fluctuating market, feed, fingerling, and equipment prices.

price of \$3.85/kg. This cost can result in an even greater savings when compared with some supermarket prices. Using this method of fish production a family with a small pond can produce 125 kg of fish over the summer with an initial investment of \$222.50. Part of this investment can be amortized over the life span of the material.

Many commercial growers and research scientists believe that if small-scale cage culture cannot produce a profit to management after labor and expenses are paid, then it is not a productive enterprise. This assumption has been questioned by millions of people who plant annual vegetable gardens. These gardens are not economically profitable but bring satisfaction to the gardener in having produced his/her own food and in knowing that the vegetables have not been adulterated with various chemicals, pesticides and preservatives. It is in this area that small-scale cage culture may have the greatest potential and ultimately the most success.

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APPENDICES

APPENDIX A

DISSOLVED OXYGEN AND TEMPERATURE DATA

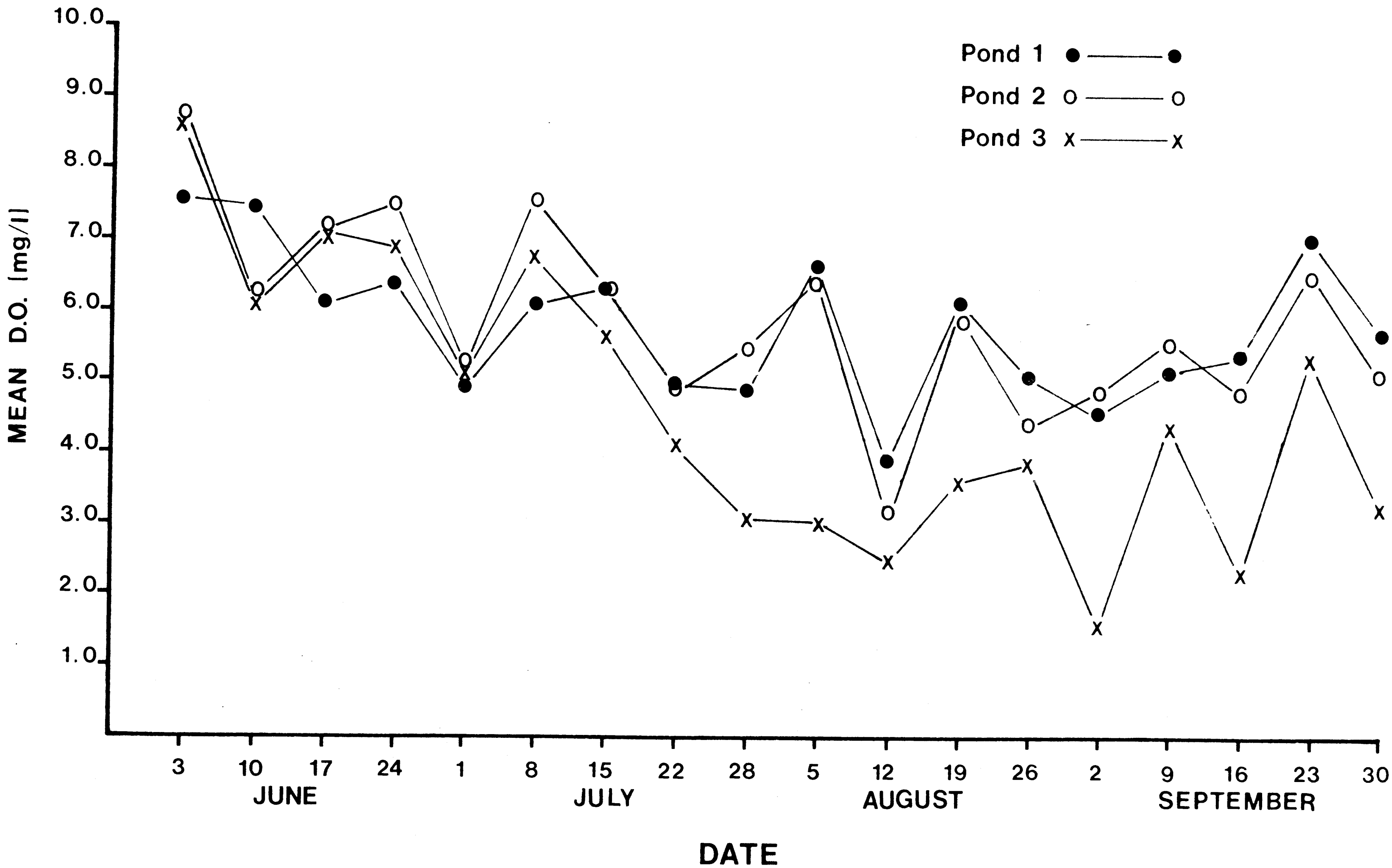
Dissolved Oxygen

The most important factor limiting growth of cage reared channel catfish in small ponds is dissolved oxygen (Newton 1980). Dissolved oxygen in these ponds often drops to lethal concentrations or at least fluctuates below the 4-5 mg/1 necessary for optimum growth (Jensen 1981a; Tiemeier and Deyoe 1980) and feed conversion efficiency (Jensen 1981a). Andrews et al. (1973) and Carlson et al. (1974) indicate that at complete oxygen saturation channel catfish consume 3.3 percent body weight of feed, whereas at 60 percent saturation and 36 percent saturation they consume 2.9 percent and 2.1 percent body weight of feed respectively. In their studies lower percent oxygen saturations were correlated with significantly smaller ($P < 0.01$) weight gains per fish.

Dissolved oxygen readings for the three experimental ponds in 1981 remained above 5 mg/1 until July 22 (Figure 11). At this point the dissolved oxygen concentration in pond 2 dropped to 1.5 mg/1. When measured on September 23, oxygen values in this pond again exceeded 5 mg/1. The low oxygen period in pond 2 covers 64 days or 46.7 percent of the growing season. Dissolved oxygen levels in ponds 1 and 3 were near or above 5 mg/1 throughout the summer except for August 12 when dissolved oxygen concentration in pond 1 dropped to 3.9 mg/1 and oxygen in pond 3 dropped to 3.1 mg/1.

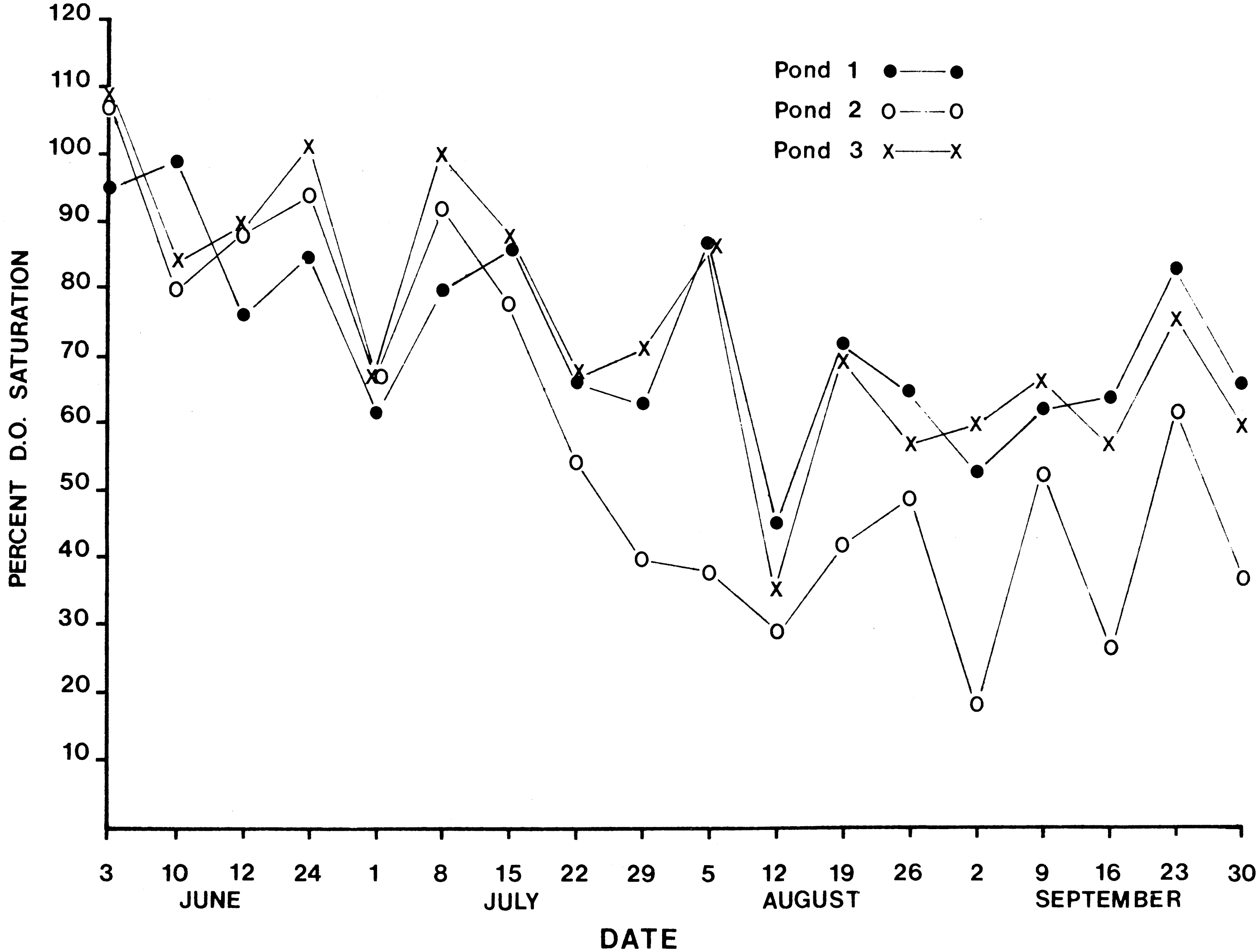
As would be expected, percent saturation of oxygen (Figure 12) in the water followed the same pattern as dissolved oxygen concentration; 95-111 percent saturation occurred in early June (June 3) and 29-45 percent saturation in mid-August (August 12). Pond 2 was below 50 percent saturation from July 29 to September 30 except on September

Figure 11. 1981 weekly mean dissolved oxygen values for ponds 1, 2, and 3 (value derived from a mean of surface, middle of cage and bottom of cage readings).



10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
MEAN D.O. (mg/l)
Pond 1
Pond 2
Pond 3
3
10
17
24
1
8
15
22
28
5
12
19
26
2
9
16
23
30
JUNE
JULY
AUGUST
SEPTEMBER
DATE

Figure 12. 1981 weekly mean percent oxygen saturation values for ponds 1, 2, and 3. (Mean derived from an average of surface, middle of cage and bottom of cage readings.)


Pond 1
Pond 2
Pond 3
PERCENT D.O. SATURATION
120
110
100
90
80
70
60
50
40
30
20
10
3
10
12
24
1
8
15
22
29
5
12
19
26
2
9
16
23
30
JUNE
JULY
AUGUST
SEPTEMBER
DATE

9 and September 23 when saturations were 53 percent and 62 percent respectively. Saturation in ponds 1 and 3 remained above 50 percent except on August 12 when it dropped to 45 percent and 35 percent respectively.

Dissolved oxygen levels in the private pond (Figure 13) were consistently high. Generally dissolved oxygen concentration was above 6 mg/1 with a mean of 6.9 mg/1 and a standard deviation of 1.6 mg/1. In contrast, the pond in which the channel catfish density experiments were run (Figure 14) had oxygen levels which ranged from 5.5-1.5 mg/1. The mean of the values was 3.6 mg/1 with a standard deviation of 1.1 mg/1 (Table 14).

Although mean dissolved oxygen values in the experimental ponds ranged from 4.6 mg/1 to 5.9 mg/1 over the growing season, the values were often below the 5 mg/1 cited for optimum growth and feed conversion efficiencies (Table 15). These marginal dissolved oxygen values have resulted in channel catfish weights averaging approximately 50 g-75 g less than would be expected (Collins 1978) under more favorable conditions. Conversion efficiencies were also somewhat higher (18.4) than those obtained by Collins (1978), (1.41-1.76), under more optimal conditions.

Mean dissolved oxygen in the private pond was higher, 6.9 mg/1, than in any of the other ponds used. This pond also contained the cage with the greatest mean weight of individual channel catfish, 348 g. However, conversion efficiencies in this pond were poor (2.01) because fish were overfed and feed was lost from the cage by wind and wave action.

The pond in which channel catfish stocked at various densities

Figure 13. 1981 biweekly mean dissolved oxygen concentrations for pond 4. (Mean derived from an average of surface, mid-cage, and bottom of cage readings.)

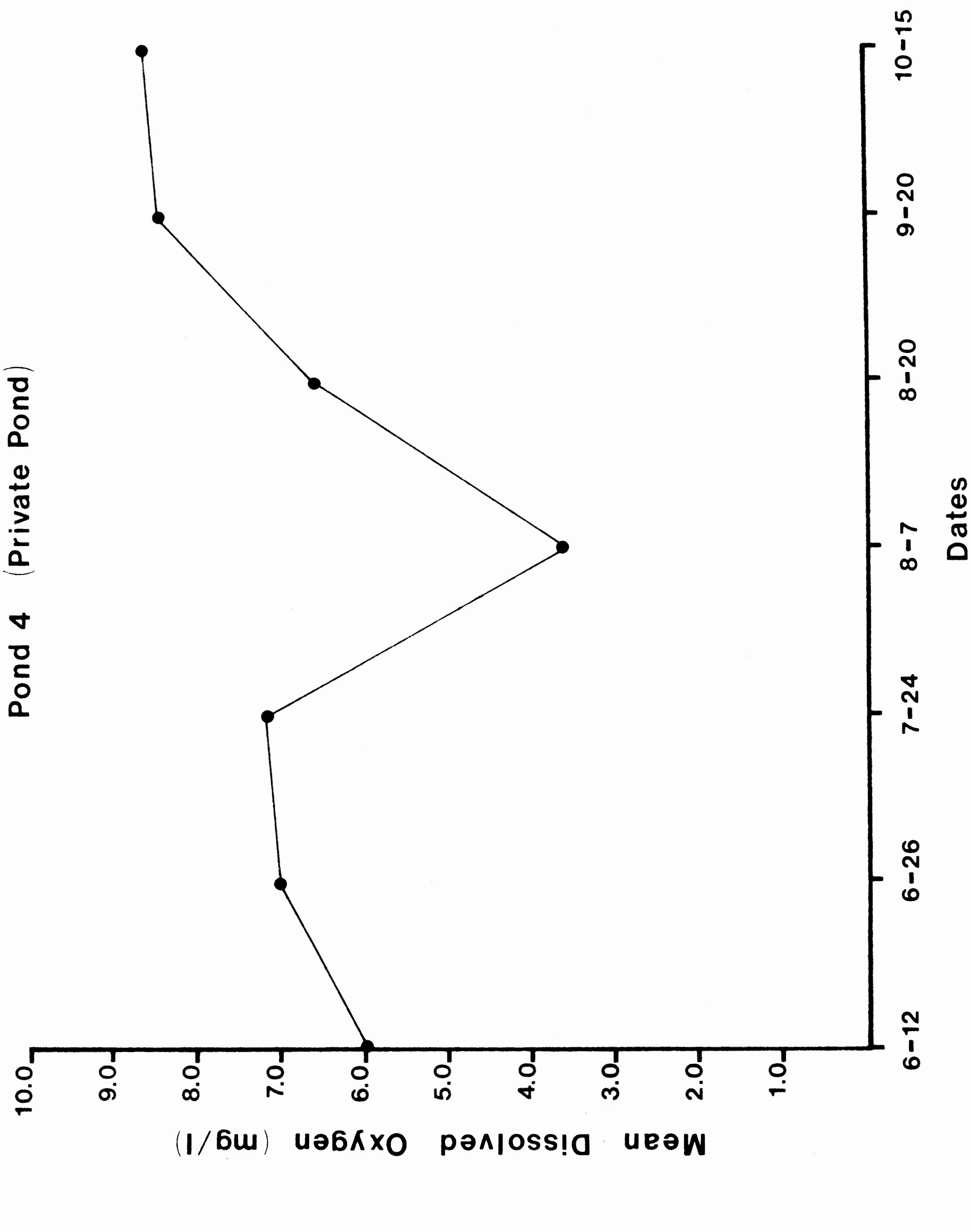

Pond 4 (Private Pond)
Mean Dissolved Oxygen (mg/l)
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
6-12
6-26
7-24
8-7
8-20
9-20
10-15
Dates

Figure 14. 1981 mean weekly dissolved oxygen values for the channel catfish density pond. (Means were derived from an average of surface, mid-cage and bottom of the cage readings.)

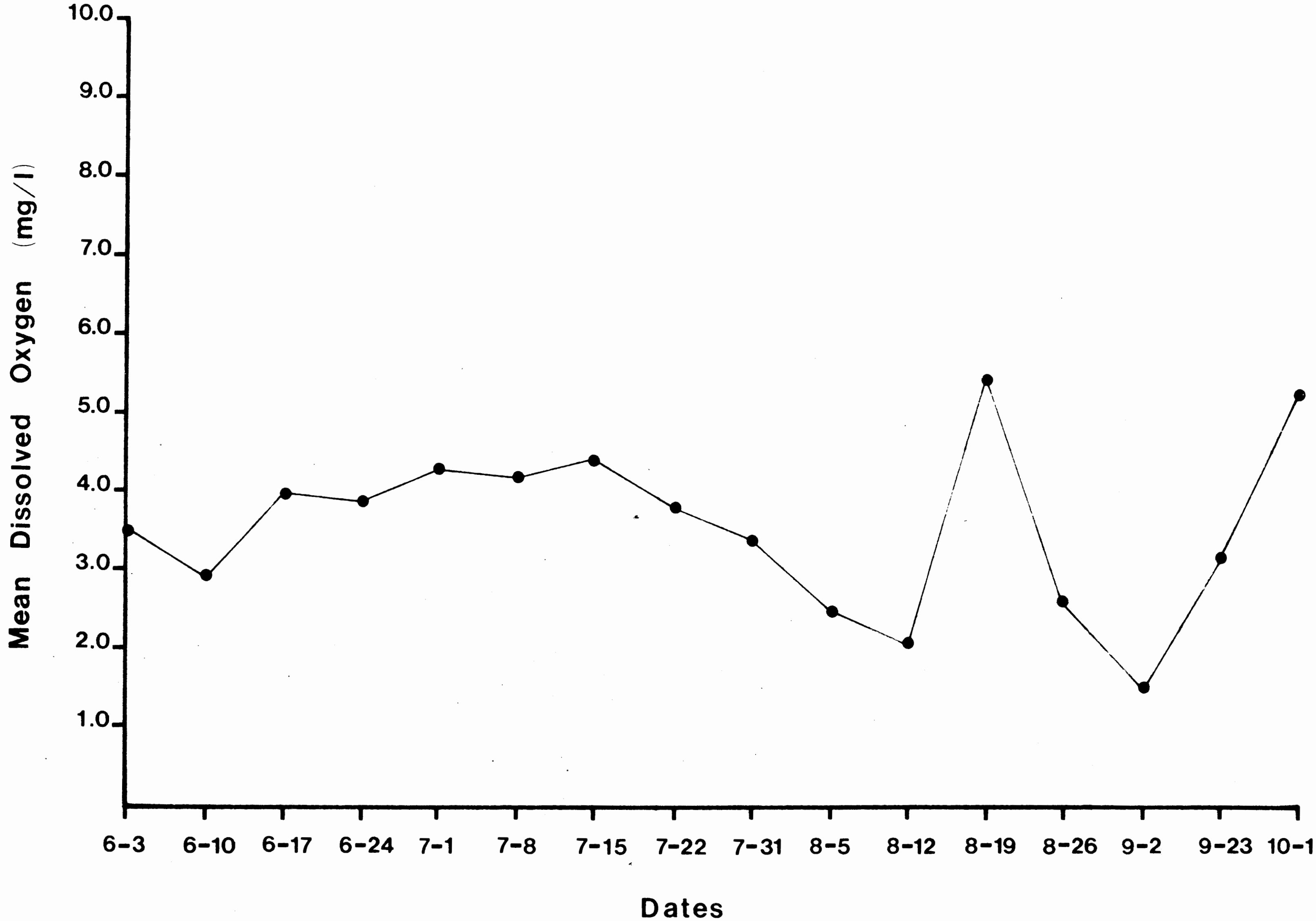

10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
Mean Dissolved Oxygen (mg/l)
6-3
6-10
6-17
6-24
7-1
7-8
7-15
7-22
7-31
8-5
8-12
8-19
8-26
9-2
9-23
10-1
Dates

Table 14. 1981 mean dissolved oxygen values in ponds used in the polyculture of channel catfish and tilapia and in the channel catfish density experiment.

Pond	(mg/1) Mean Dissolved oxygen	(mg/1) Std. deviation	(mg/1) Range
1	5.8	1.04	3.9-7.7
2	4.6	1.95	1.6-8.6
3	5.9	1.36	3.1-8.8
4	6.9	1.63	3.8-8.6
Catfish density pond	3.6	1.11	1.5-5.5

Table 15. 1981 mean monthly dissolved oxygen values in ponds used in the polyculture of channel catfish and tilapia and in the channel catfish density experiment.

Pond	month	mean dissolved oxygen (mg/1)	(mg/1) Std. deviation	(mg/1) Range
1	June	6.9	0.78	6.1-7.7
1	July	5.4	0.70	4.9-6.3
1	August	5.5	1.24	3.9-6.7
1	September	5.6	0.95	4.6-7.1
2	June	7.2	1.04	6.1-8.6
2	July	5.0	1.44	3.1-6.8
2	August	3.2	0.64	2.5-3.1
2	September	3.4	1.55	1.6-5.4
3	June	7.4	1.13	6.1-8.8
3	July	5.9	1.07	4.9-7.6
3	August	5.0	1.56	3.1-6.5
3	September	5.4	0.71	4.9-6.6
4	June	6.6	0.71	6.1-7.1
4	July	7.2	--	7.2
4	August	5.2	1.98	3.8-6.6
4	September	8.5	--	8.5
catfish density pond	June	3.6	0.52	2.9-4.0
	July	4.0	0.46	3.3-4.4
	August	3.2	1.58	2.1-5.5
	September	3.3	1.94	1.5-5.3

were studied exhibited the lowest mean dissolved oxygen concentration (3.6 mg/1) of any of the ponds studied. This low oxygen level was reflected in very poor weight gains (mean final weight of 144.3 g to 152.0 g per catfish) for fish from this pond.

Temperature

Pond temperatures in 1981 varied from 25 C to 30 C during June and July. This temperature is optimal for channel catfish feeding and is also the temperature at which highest growth rates and feed conversion efficiencies have been observed (Shrable et al. 1969; Andrews and Stickney 1972). However, in August, frequent storm events and the passage of cold fronts caused water temperatures to fluctuate sharply (Table 16). Rapid changes in August water temperature caused reduced fish feeding for a period of one to 10 days. Increase in temperature appeared to affect feeding activity less than decreased temperatures. This effect on feeding may result from increases in water temperature tending to occur over several days while decreases occurred within hours. Sudden temperature changes may disturb metabolic processes and thus result in a cessation of feeding activity. Randolph and Clemens (1976) observed that fish acclimated to increasing temperatures generally did not feed at temperatures below those of the previous week even though the values appeared to be within acceptable limits.

Although temperature and dissolved oxygen concentrations are closely linked, reduced dissolved oxygen concentration was not the cause of reduced feeding activity during these temperature fluctuations. Further evidence to support this conclusion is given by the fact that dissolved oxygen ranged from 3 mg/1 to 7 mg/1 over the August period.

Table 16. 1981 mean monthly temperature values in ponds used in the polyculture of channel catfish and tilapia and in the channel catfish density experiment.

Pond	Month	Mean temperature C	Std. deviation C	Range C
1	June	26.9	2.41	25.2-29.4
1	July	27.5	1.34	25.5-29.4
1	August	23.3	3.28	20.1-27.3
1	September	21.5	0.46	21.0-22.0
2	June	27.0	2.63	24.2-29.8
2	July	27.5	1.38	25.7-29.5
2	August	23.2	3.53	20.0-27.5
2	September	21.4	1.15	20.6-23.4
3	June	27.5	2.82	24.5-30.2
3	July	28.2	1.45	26.4-30.3
3	August	23.3	3.97	19.9-27.6
3	September	21.9	1.09	21.0-23.7
4	June	28.5	1.41	27.5-29.5
4	July	27.4	--	27.4
4	August	25.9	1.84	24.6-27.2
4	September	20.1	--	20.1
Channel catfish density pond	June	26.0	2.57	23.6-28.2
	July	26.4	0.93	25.6-27.7
	August	22.4	3.99	17.3-26.8
	September	19.9	2.46	17.6-22.5

Dissolved oxygen levels of this range were not observed to affect feeding behavior when water temperature was relatively stable (Randolph and Clemens 1976). From these observations it seems reasonable that the inability of small shallow ponds to buffer the effects of atmospheric variation is a key factor in reduced production potential per acre of these ponds as compared with larger, deeper bodies of water.

APPENDIX B

CHANNEL CATFISH AND TILAPIA

PRODUCTION DATA

Table 17. Production per cage for channel catfish-tilapia polyculture.

Pond	treatment	feed	(kg) Int. wt. of fish	(kg) Final wt. of fish	(kg) Net prod.	Conversion efficiency
1	0	161.050	9.148	110.978	101.830	1.58
1	10	174.876	9.366	104.397	95.032	1.84
1	50	189.125	10.237	117.405	107.168	1.77
2	0	225.300	9.148	129.462	120.314	1.87
2	10	234.375	9.366	130.121	120.655	1.94
2	50	232.050	10.237	134.037	123.800	1.87
3	0	199.100	9.148	129.322	120.174	1.66
3	10	199.650	9.366	128.287	188.922	1.68
3	50	213.850	10.237	139.272	129.035	1.66
4	0	225.435	9.148	116.127	106.979	2.11
4	10	237.384	9.366	124.774	115.409	2.06
4	50	261.973	10.237	140.516	130.280	2.01

Table 18. Catfish production per cage, channel catfish-tilapia polyculture experiment.

Pond	trt.	(kg) Int. wt. of fish	(kg) Final wt. of fish	Net prod.	% surv.	(g) X	K	CV	% Harv.	No. of harv. fish
1	0	9.148	110.978	101.83	99	294.5	1.341	.50	32	128
1	10	8.919	101.526	92.60	97	299.6	1.223	.36	32	125
1	50	8.005	102.802	94.80	98	306.1	1.231	.32	38	133
2	0	9.148	129.462	120.37	99	328.5	1.122	.38	46	184
2	10	8.919	127.233	118.31	99	307.6	1.068	.34	38	148
2	50	8.005	119.425	111.42	100	358.2	1.071	.33	52	182
3	0	9.148	129.322	120.17	99	333.0	1.144	.35	42	168
3	10	0.919	124.790	115.86	99	338.5	1.154	.39	46	179
3	50	8.005	120.552	112.55	96	366.2	1.144	.42	54	189
4	0	9.148	116.127	106.98	100	246.9	1.275	.46	20	80
4	10	8.919	122.566	113.64	100	306.7	1.250	.39	40	156
4	50	8.005	130.464	122.46	100	384.0	1.366	.39	54	189

Table 19. Tilapia production data per cage, channel catfish-tilapia polyculture experiment.

Pond	trt.	(kg) Int. wt. of fish	(kg) Final wt. of fish	Net prod.	% surv.	$\bar{X}$	K	CV	% Harv.	No. of harv. fish
1	0	--	--	--	--	--	--	--	--	--
1	10	0.446	2.871	2.425	100	287.1	2.341	.34	50	5
1	50	2.232	14.603	12.371	100	296.3	2.528	.26	84	42
2	0	--	--	--	--	--	--	--	--	--
2	10	0.446	2.788	2.342	90	309.8	2.338	.26	78	8
2	50	2.232	14.612	12.380	98	298.2	2.276	.23	88	44
3	0	--	--	--	--	--	--	--	--	--
3	10	0.446	3.497	3.051	100	349.7	2.371	.27	100	10
3	50	2.232	18.720	16.488	100	374.4	2.388	.25	96	48
4	0	--	--	--	--	--	--	--	--	--
4	10	0.446	2.208	1.762	80	276.0	2.381	.22	75	8
4	50	2.232	10.052	7.820	80	251.3	2.393	.30	55	28

Table 20. Production of channel catfish grown at various densities.

stocking density/m^3	350	400	450
harvest number	331	390	431
percent survival	94.6	97.5	95.8
amount fed (kg)	71.350	84.000	95.350
initial weight (kg)	8.004	9.148	10.291
gross prod. (kg)	47.763	59.284	64.049
net prod. (kg)	39.759	50.136	53.758
average wt./fish (g)	144.3	152.0	148.6
conversion efficiency	1.79	1.68	1.77

APPENDIX C

WEIGHT FREQUENCY DISTRIBUTION FOR

CAGED CHANNEL CATFISH

Figure 15. Weight frequency distribution of channel catfish from cages containing 0 tilapia-400 channel catfish.

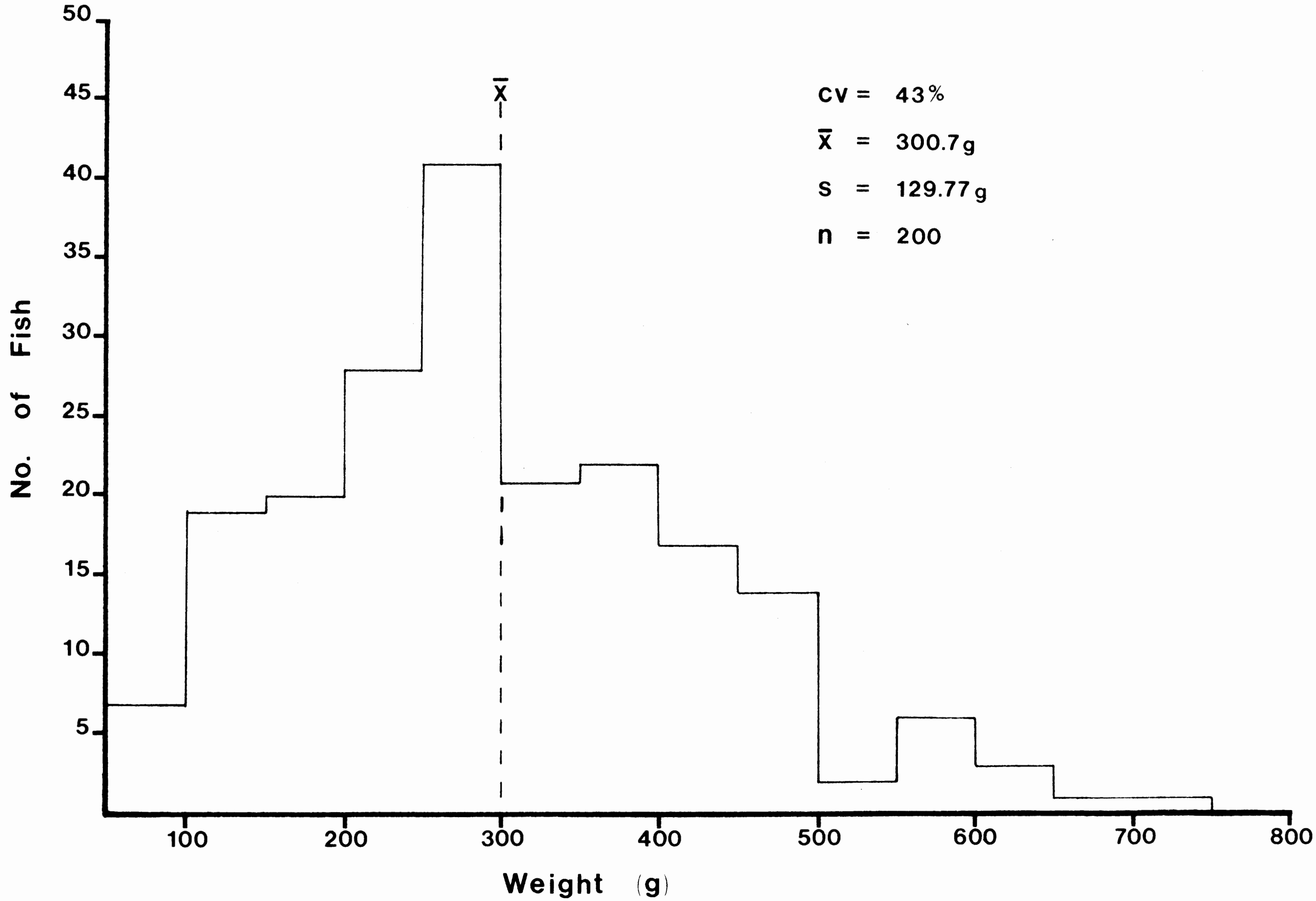

50
45
40
35
30
25
20
15
10
5
No. of Fish
x̄
cv = 43%
x̄ = 300.7g
s = 129.77g
n = 200
100
200
300
400
500
600
700
800
Weight (g)

Figure 16. Weight frequency distribution of channel catfish from cages containing 10 tilapia-390 channel catfish.

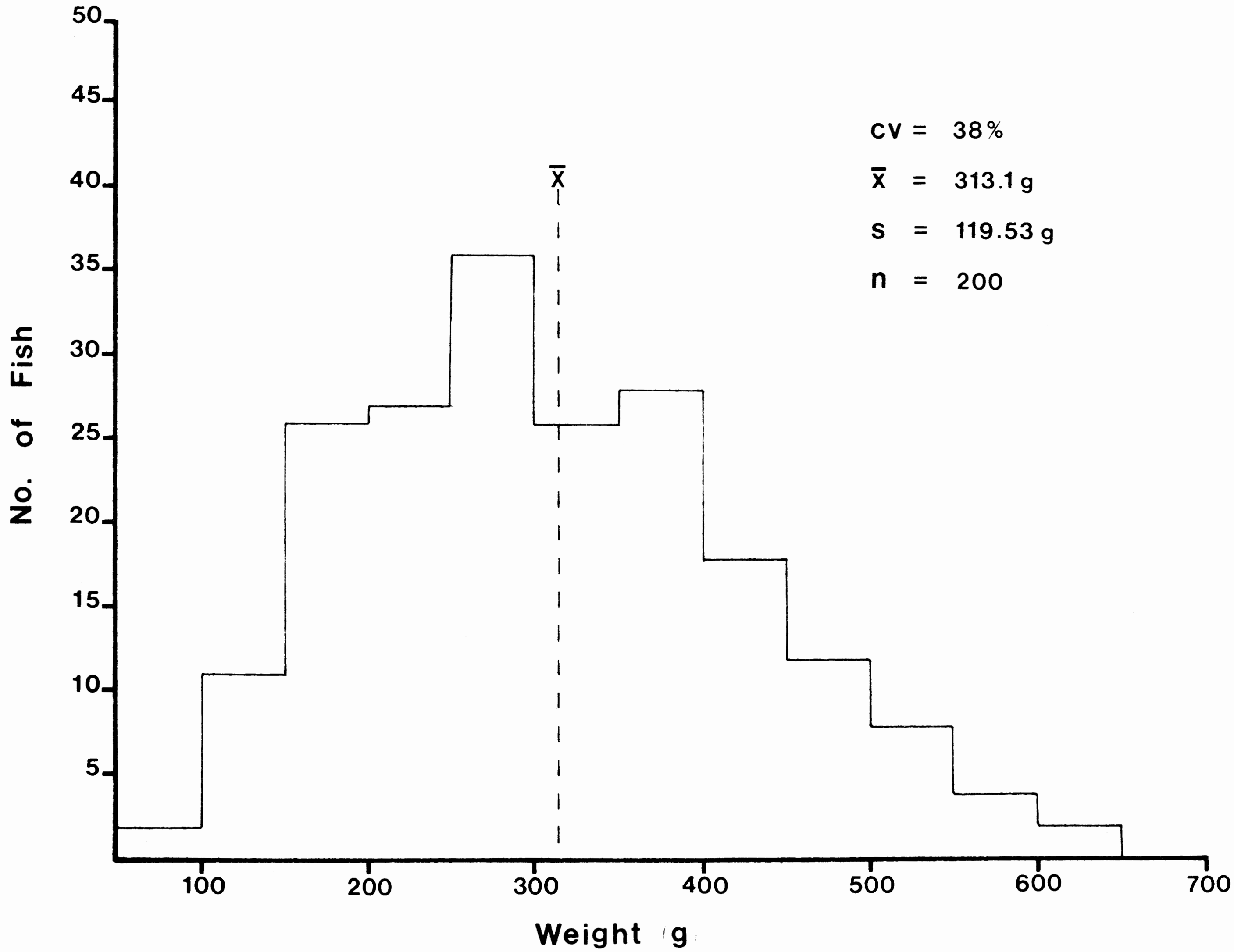
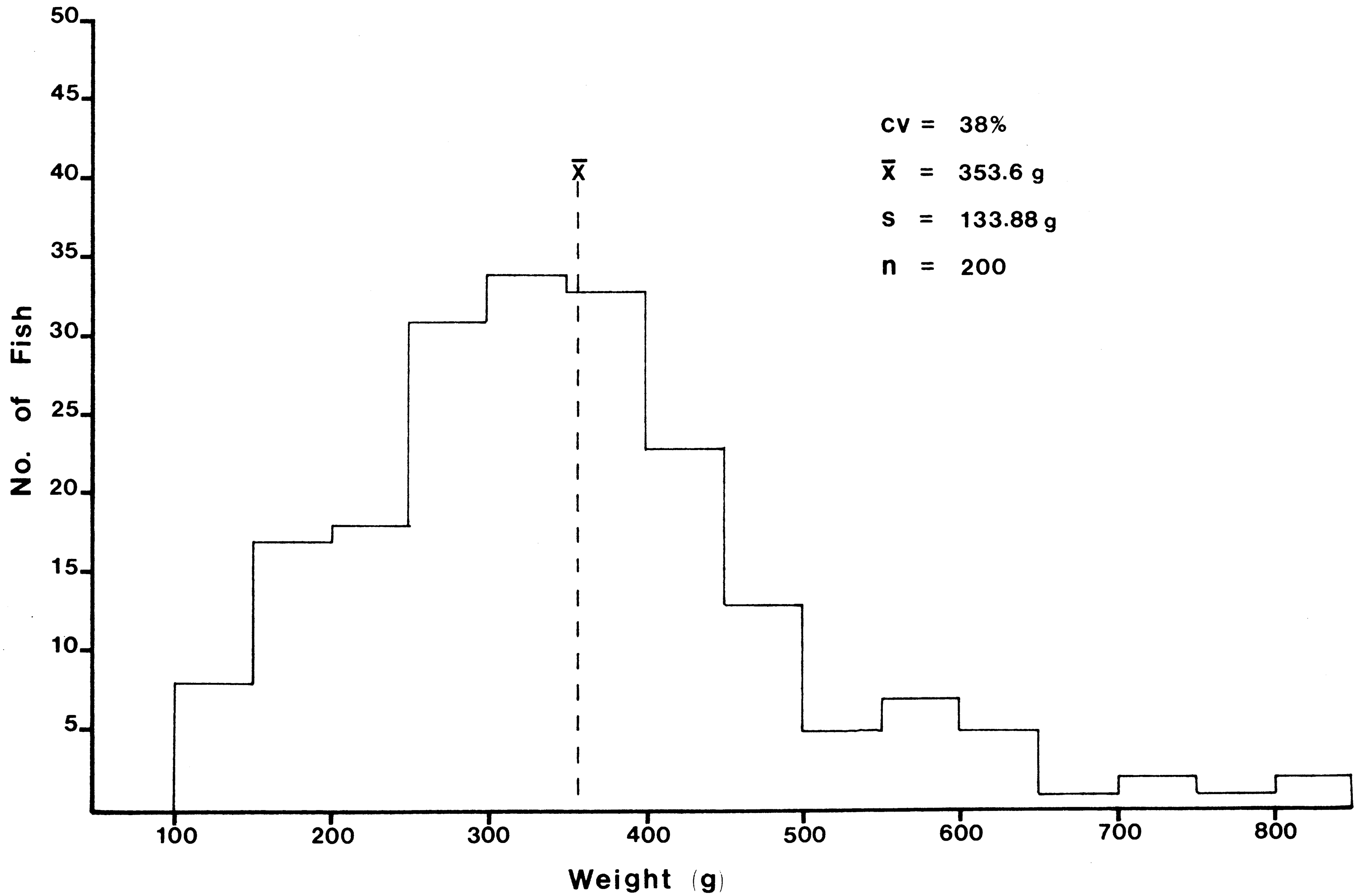
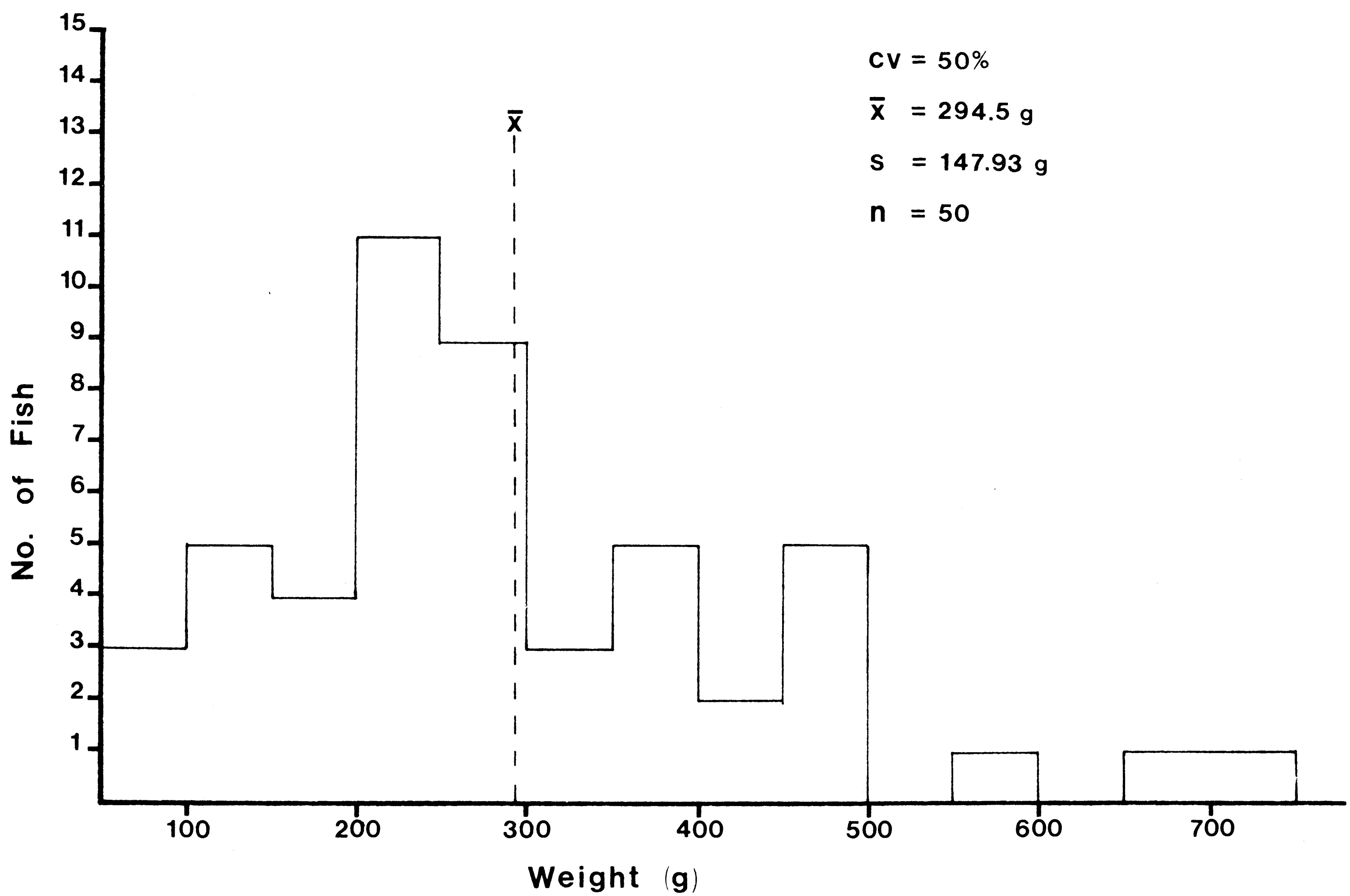

No. of Fish
Weight (g)
cv = 38%
x̄ = 313.1 g
s = 119.53 g
n = 200
x̄
50
45
40
35
30
25
20
15
10
5
100
200
300
400
500
600
700

Figure 17. Weight frequency distribution of channel catfish from cages containing 50 tilapia-350 channel catfish.



cv = 38%
x̄ = 353.6 g
s = 133.88 g
n = 200
x̄
No. of Fish
50
45
40
35
30
25
20
15
10
5
100
200
300
400
500
600
700
800
Weight (g)

Figure 18. Weight frequency distribution of channel catfish (pond 1) from the cage containing 0 tilapia-400 channel catfish.



cv = 50%
x̄ = 294.5 g
s = 147.93 g
n = 50
x̄
No. of Fish
Weight (g)
100
200
300
400
500
600
700
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

Figure 19. Weight frequency distribution of channel catfish (pond 1) from the cage containing 10 tilapia-390 channel catfish.

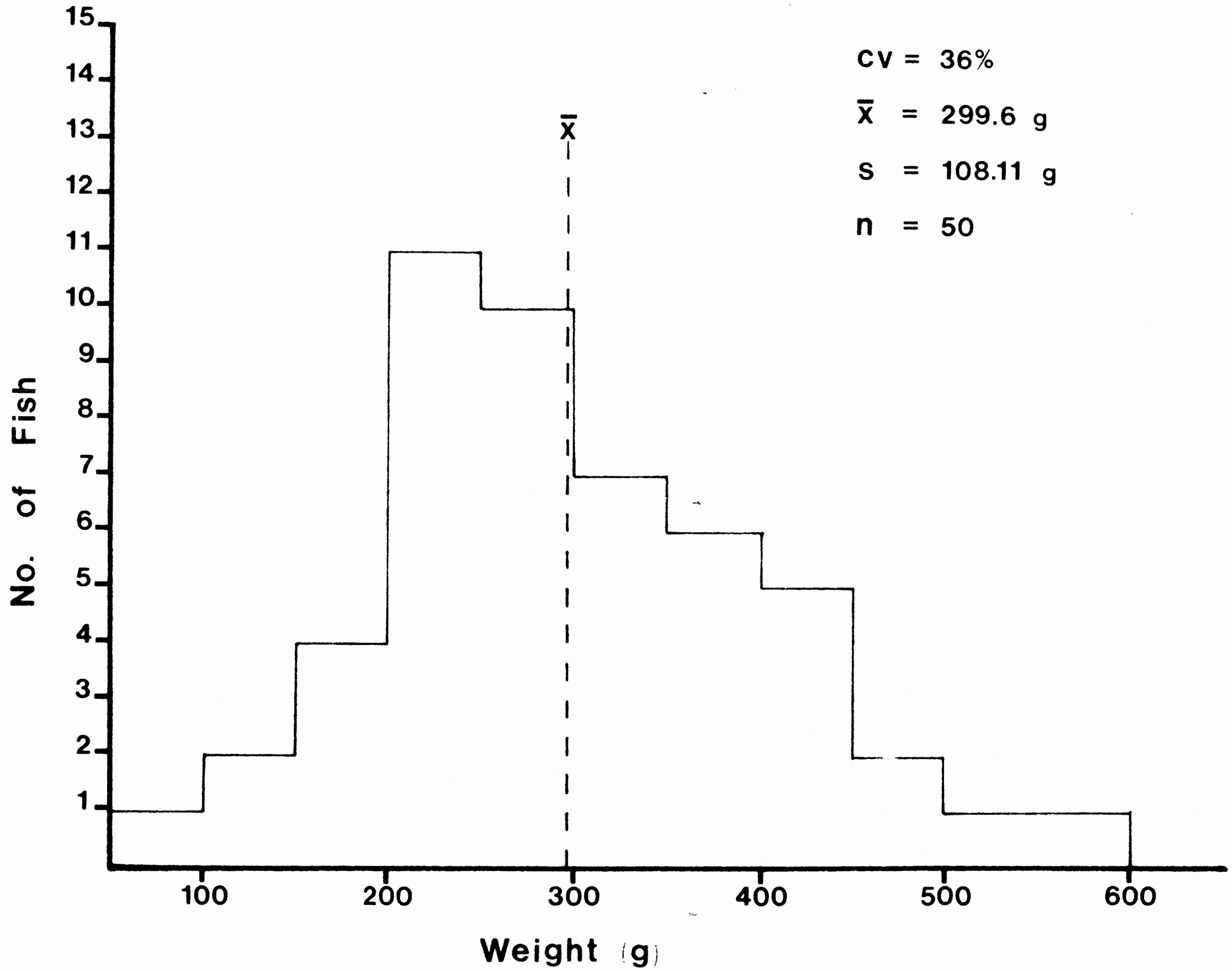

cv = 36%
x̄ = 299.6 g
s = 108.11 g
n = 50
x̄
No. of Fish
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
100
200
300
400
500
600
Weight (g)

Figure 20. Weight frequency distribution of channel catfish (pond 1) from the cage containing 50 tilapia-350 channel catfish.

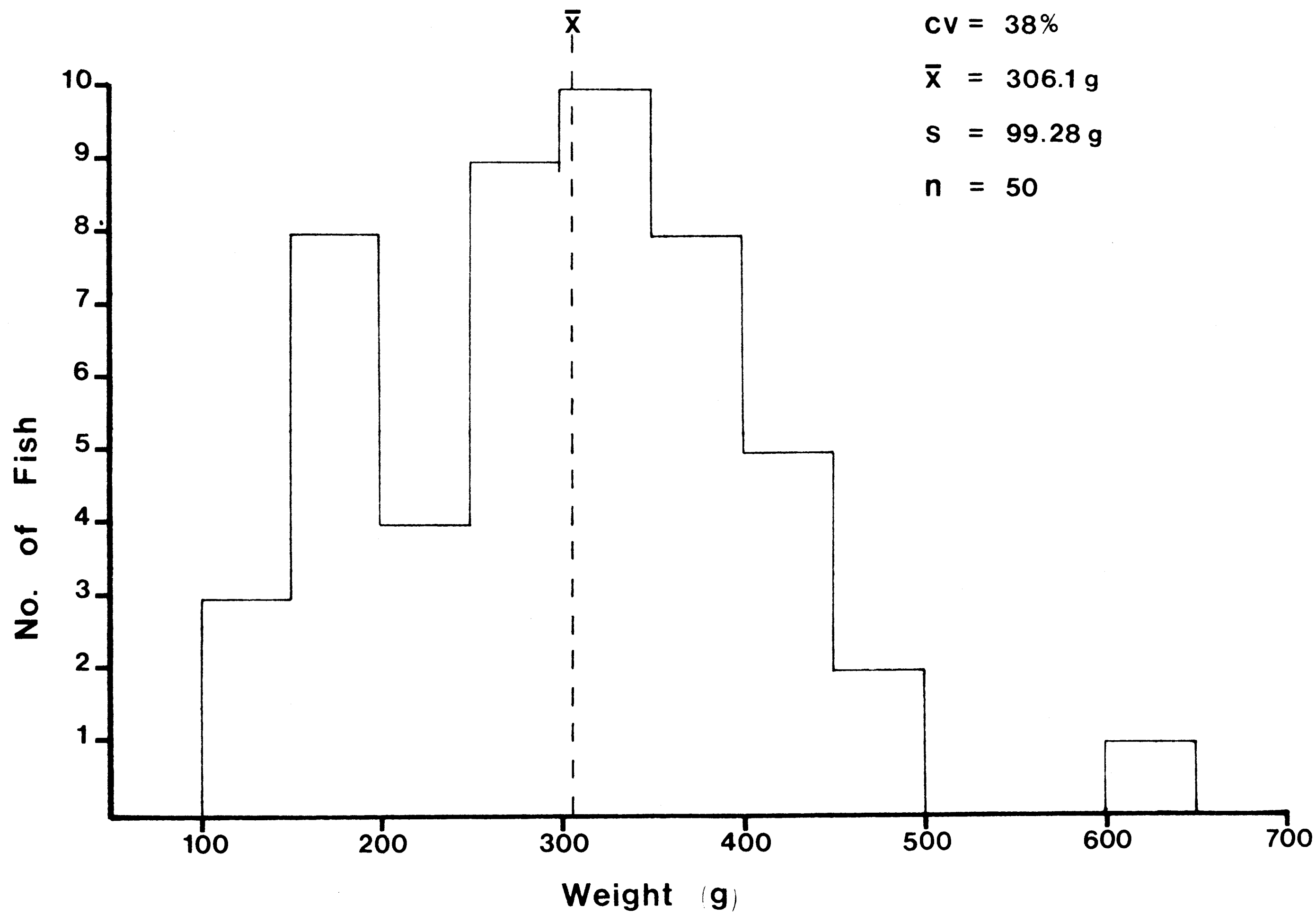
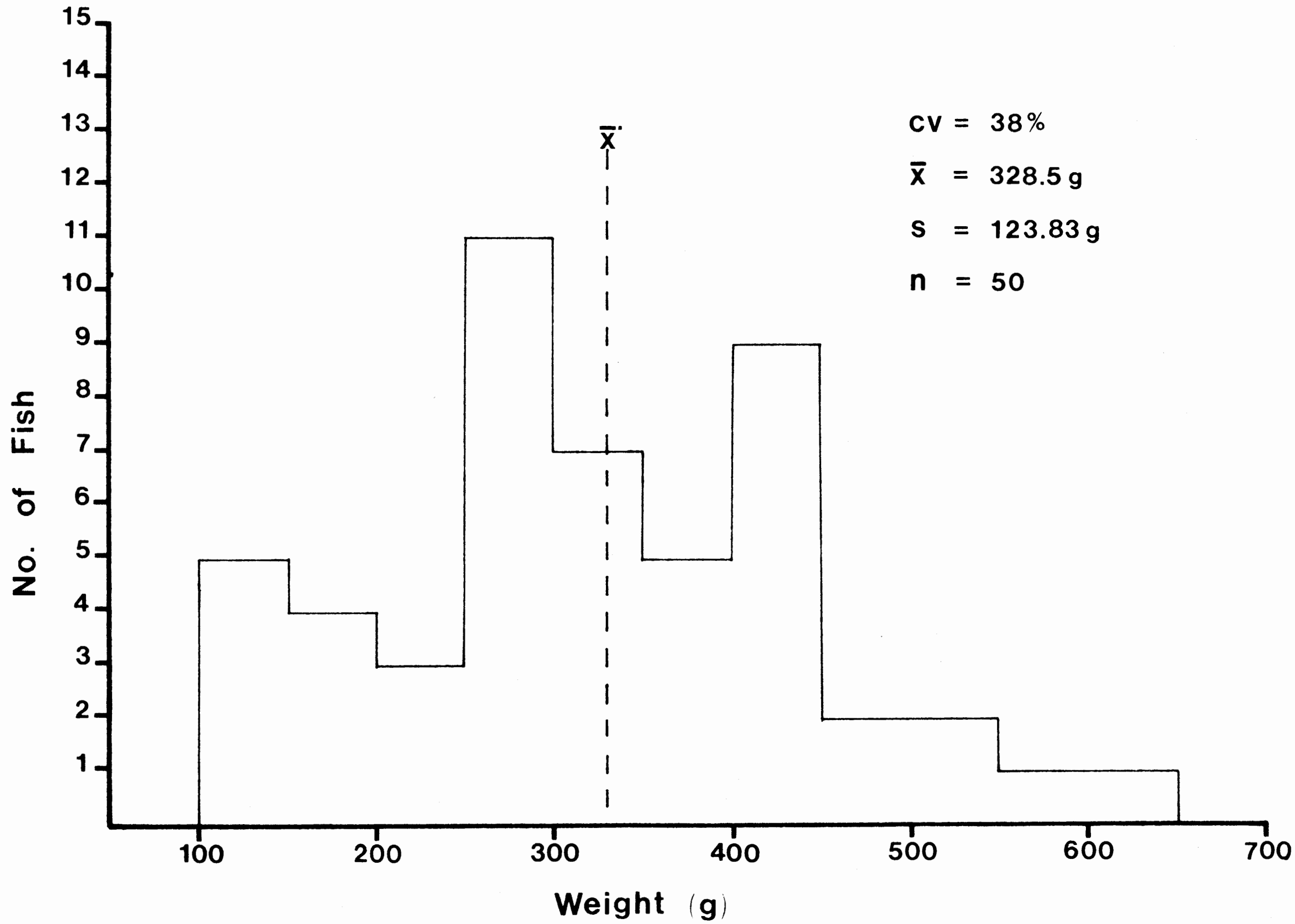

x̄
cv = 38%
x̄ = 306.1 g
s = 99.28 g
n = 50
No. of Fish
10
9
8
7
6
5
4
3
2
1
100
200
300
400
500
600
700
Weight (g)

Figure 21. Weight frequency distribution of channel catfish (pond 2) from the cage containing 0 tilapia-400 channel catfish.



cv = 38%
x̄ = 328.5 g
s = 123.83 g
n = 50
x̄
No. of Fish
Weight (g)

Figure 22. Weight frequency distribution of channel catfish (pond 2) from the cage containing 10 tilapia-390 channel catfish.

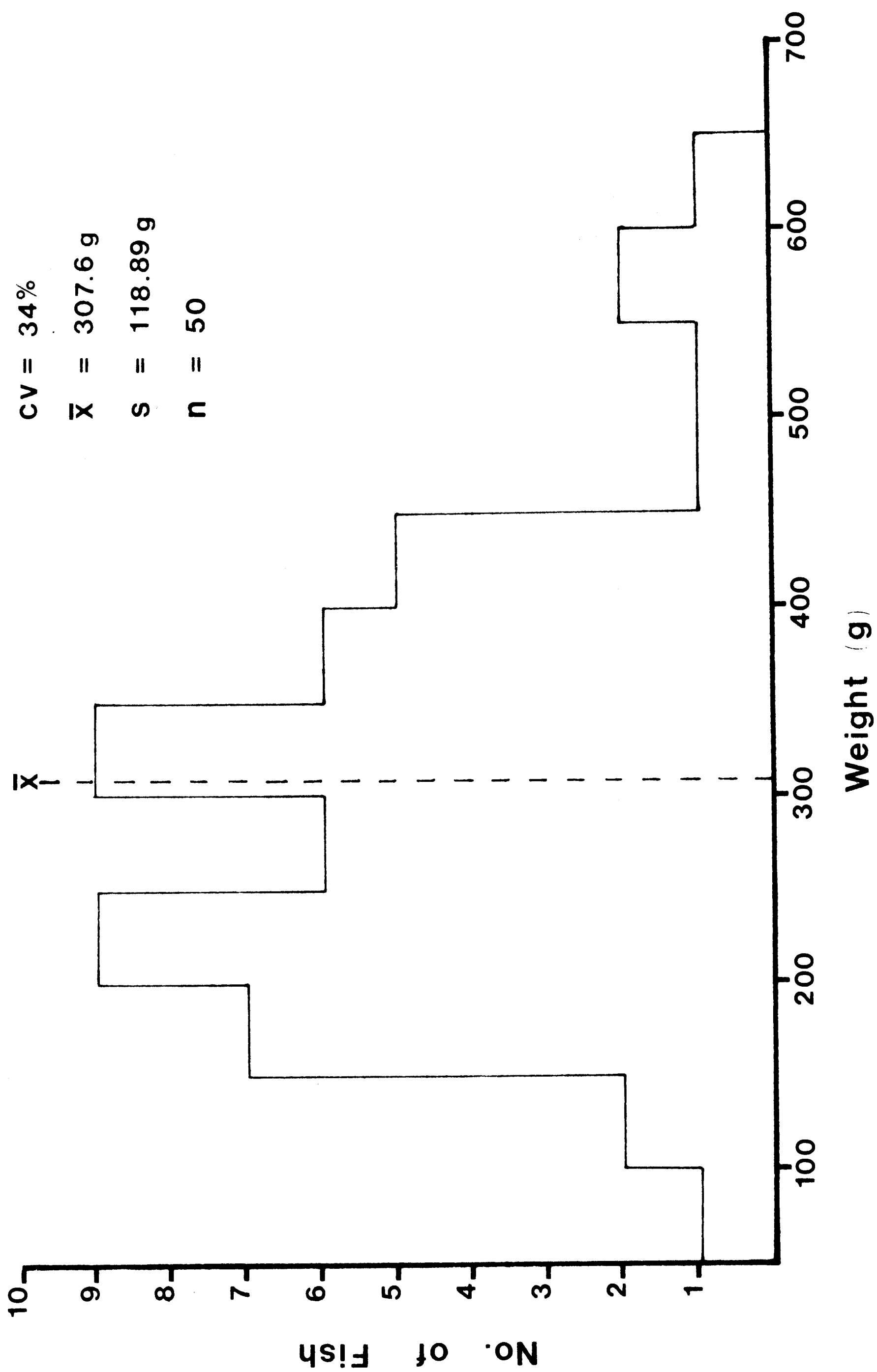

CV = 34%
$\bar{X}$ = 307.6 g
s = 118.89 g
n = 50
$\bar{X}$
No. of Fish
1
2
3
4
5
6
7
8
9
10
100
200
300
400
500
600
700
Weight (g)

Figure 23. Weight frequency distribution of channel catfish (pond 2) from the cage containing 50 tilapia-350 channel catfish.

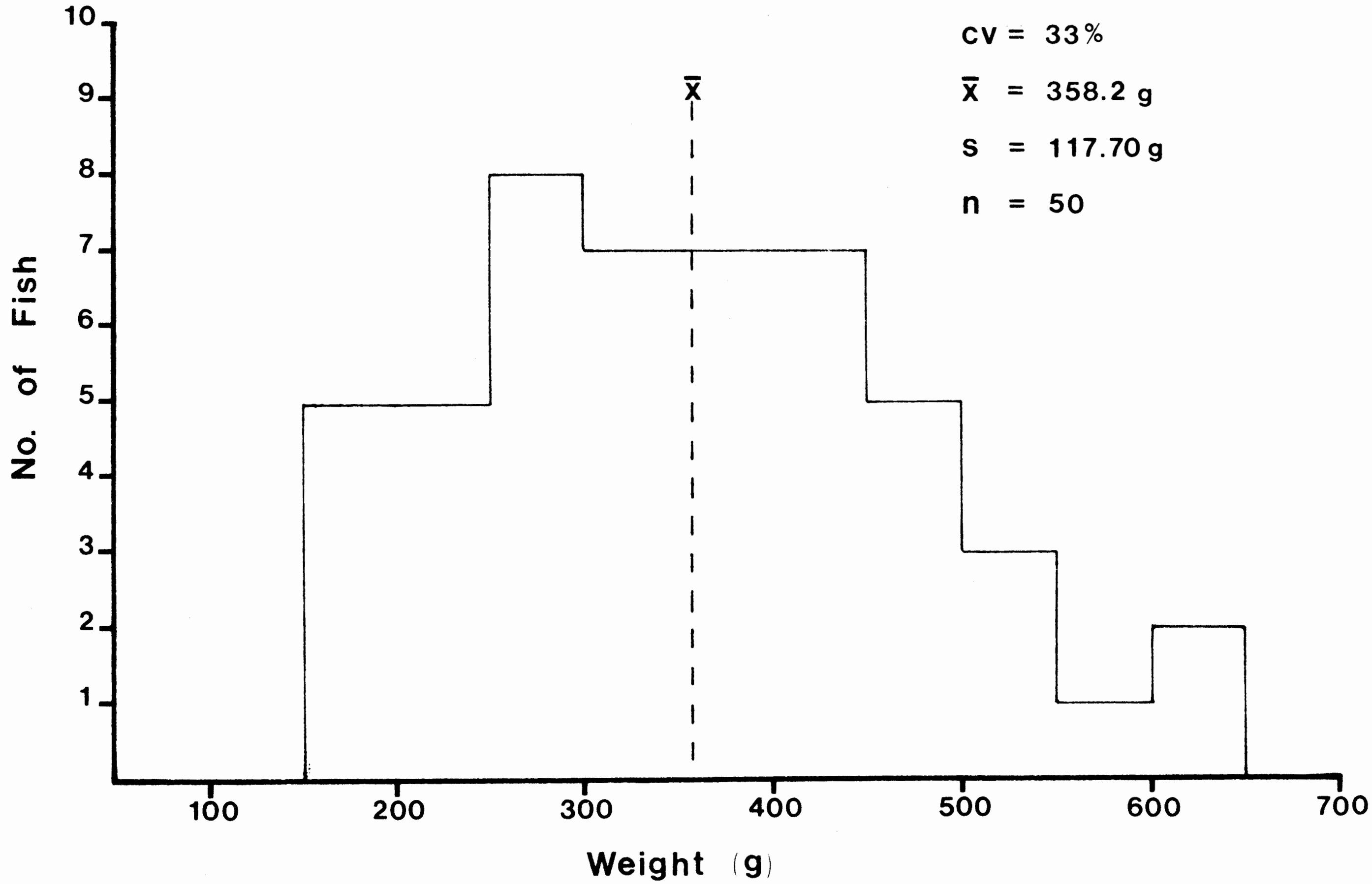

cv = 33%
$\bar{x}$ = 358.2 g
s = 117.70 g
n = 50
$\bar{x}$
No. of Fish
10
9
8
7
6
5
4
3
2
1
100
200
300
400
500
600
700
Weight (g)

Figure 24. Weight frequency distribution of channel catfish (pond 3) from the cage containing 0 tilapia-400 channel catfish.

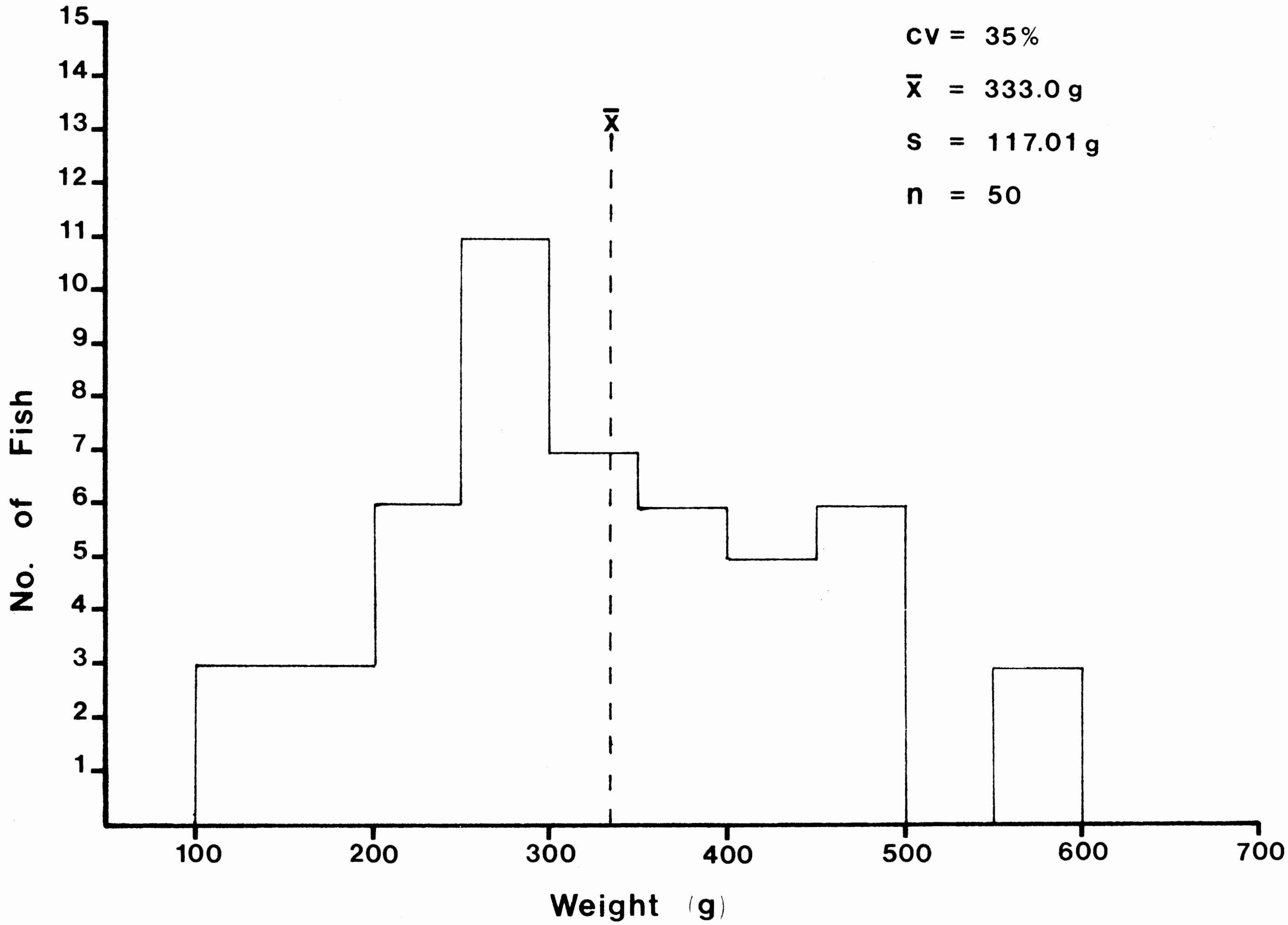

cv = 35%
x̄ = 333.0 g
s = 117.01 g
n = 50
x̄
No. of Fish
Weight (g)
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
100
200
300
400
500
600
700

Figure 25. Weight frequency distribution of channel catfish (pond 3) from the cage containing 10 tilapia-390 channel catfish.

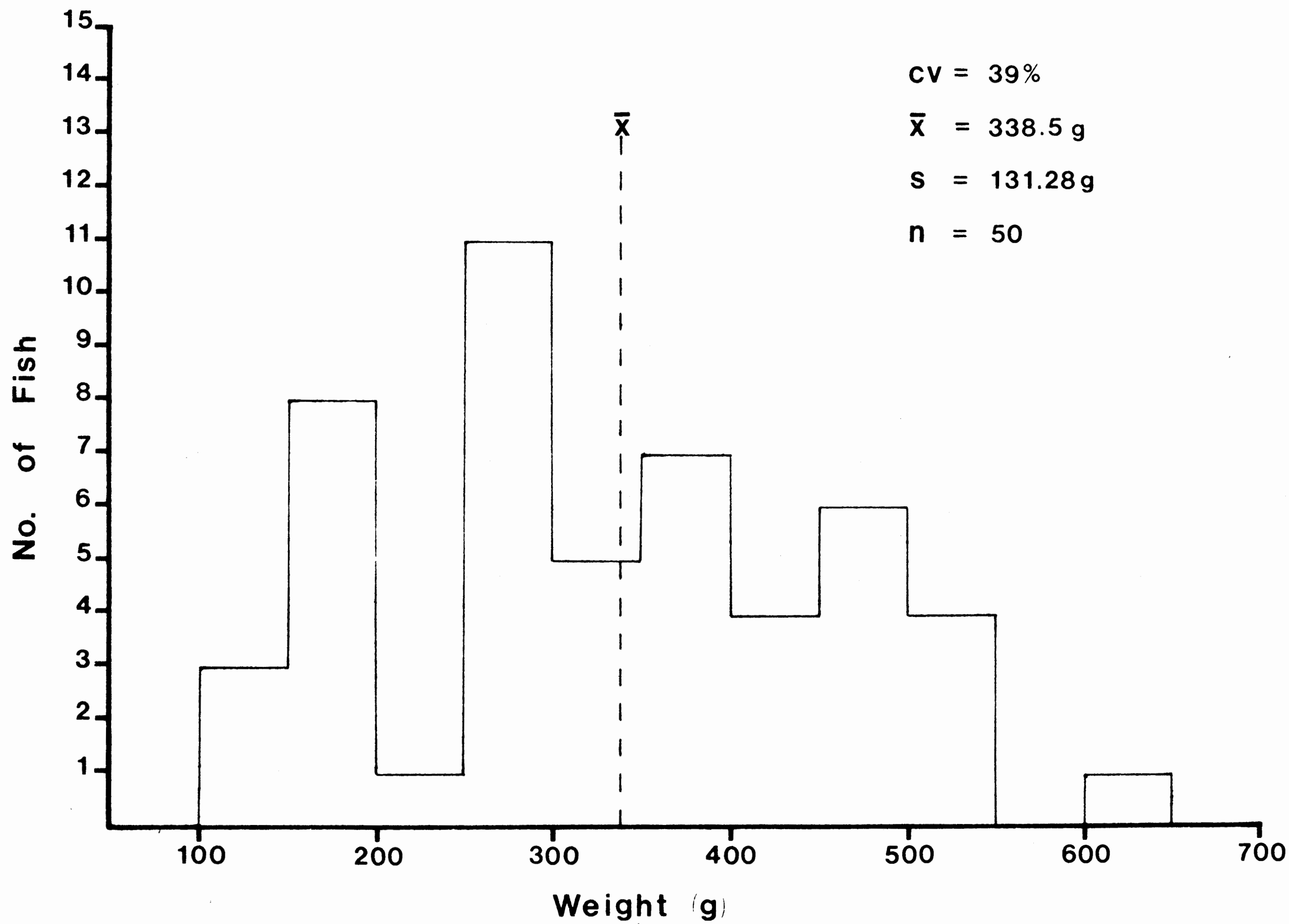

cv = 39%
x̄ = 338.5 g
s = 131.28 g
n = 50
x̄
No. of Fish
Weight (g)
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
100
200
300
400
500
600
700

Figure 26. Weight frequency distribution of channel catfish (pond 3) from the cage containing 50 tilapia-350 channel catfish.

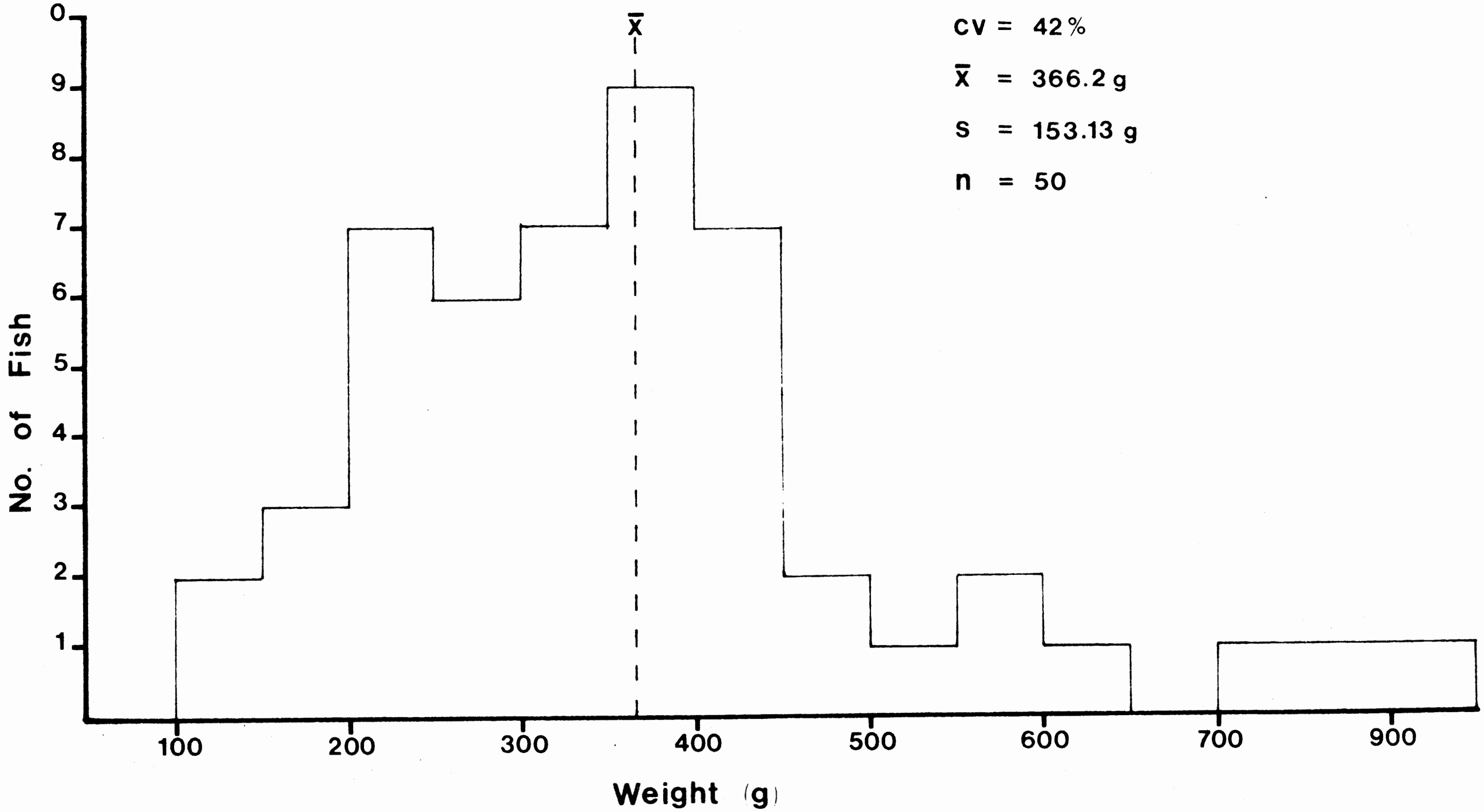

cv = 42%
$\bar{x}$ = 366.2 g
s = 153.13 g
n = 50
$\bar{x}$
No. of Fish
Weight (g)
0
9
8
7
6
5
4
3
2
1
100
200
300
400
500
600
700
900

Figure 27. Weight frequency distribution of channel catfish (pond 4) from the cage containing 0 tilapia-400 channel catfish.

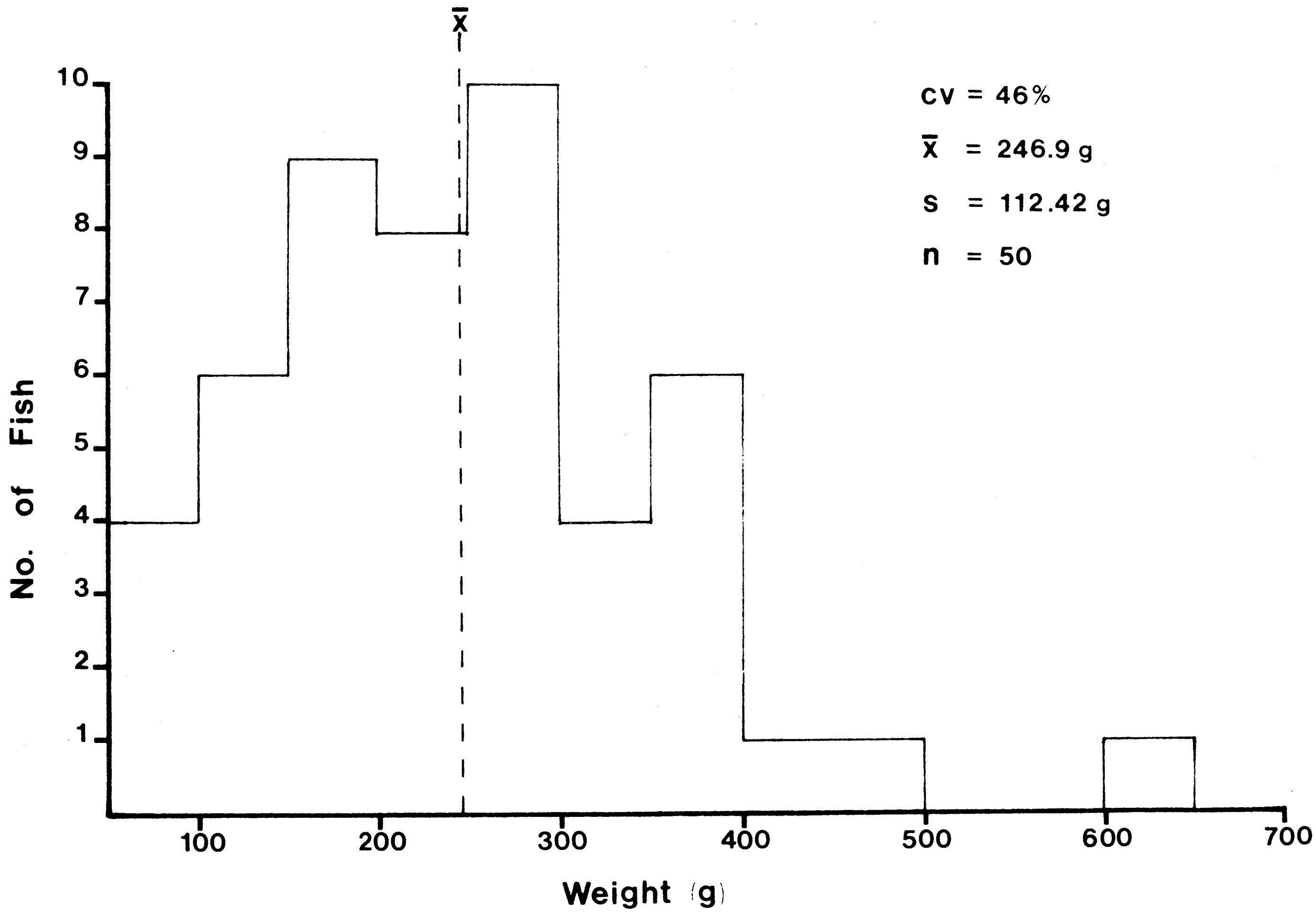
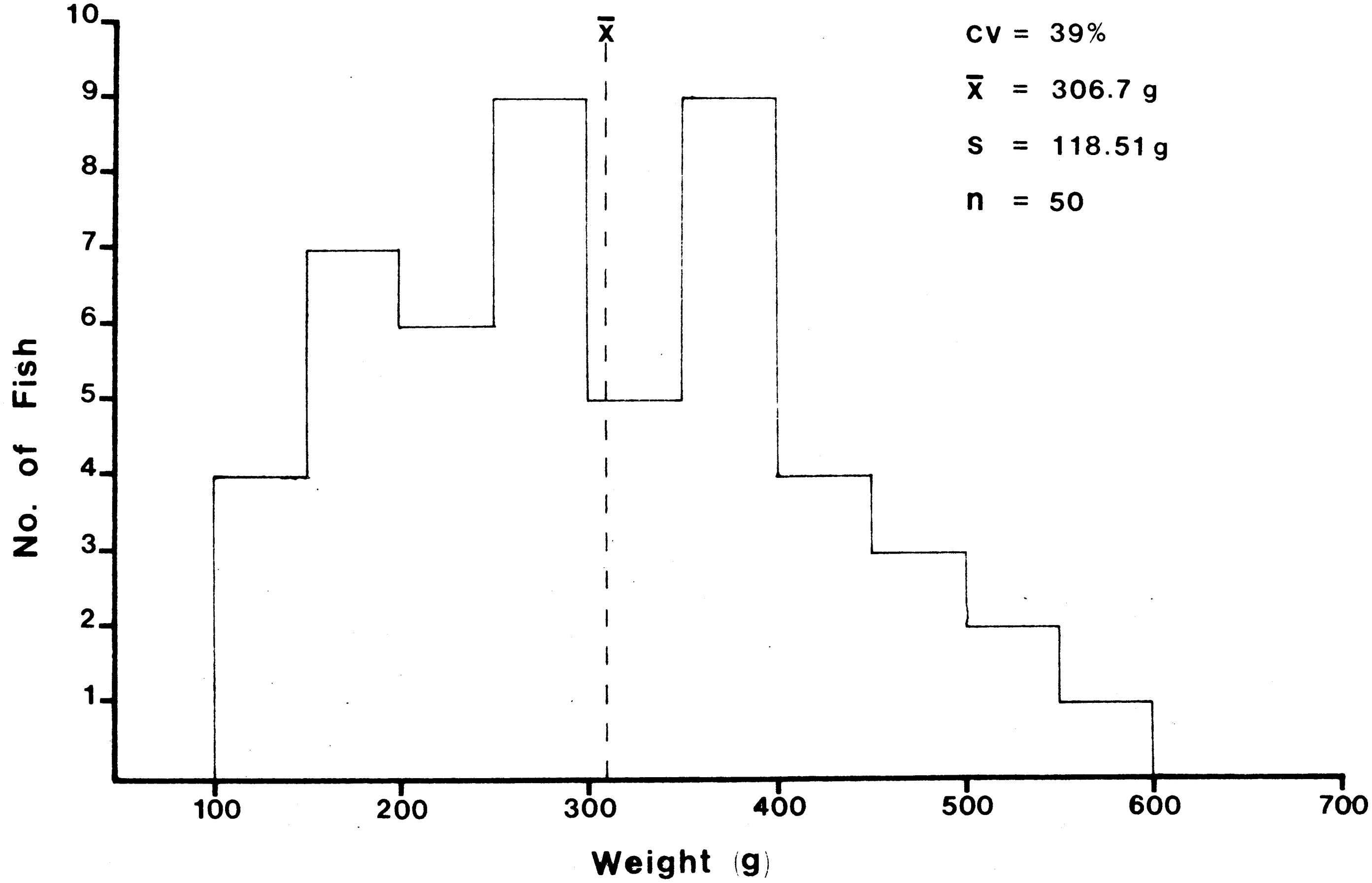
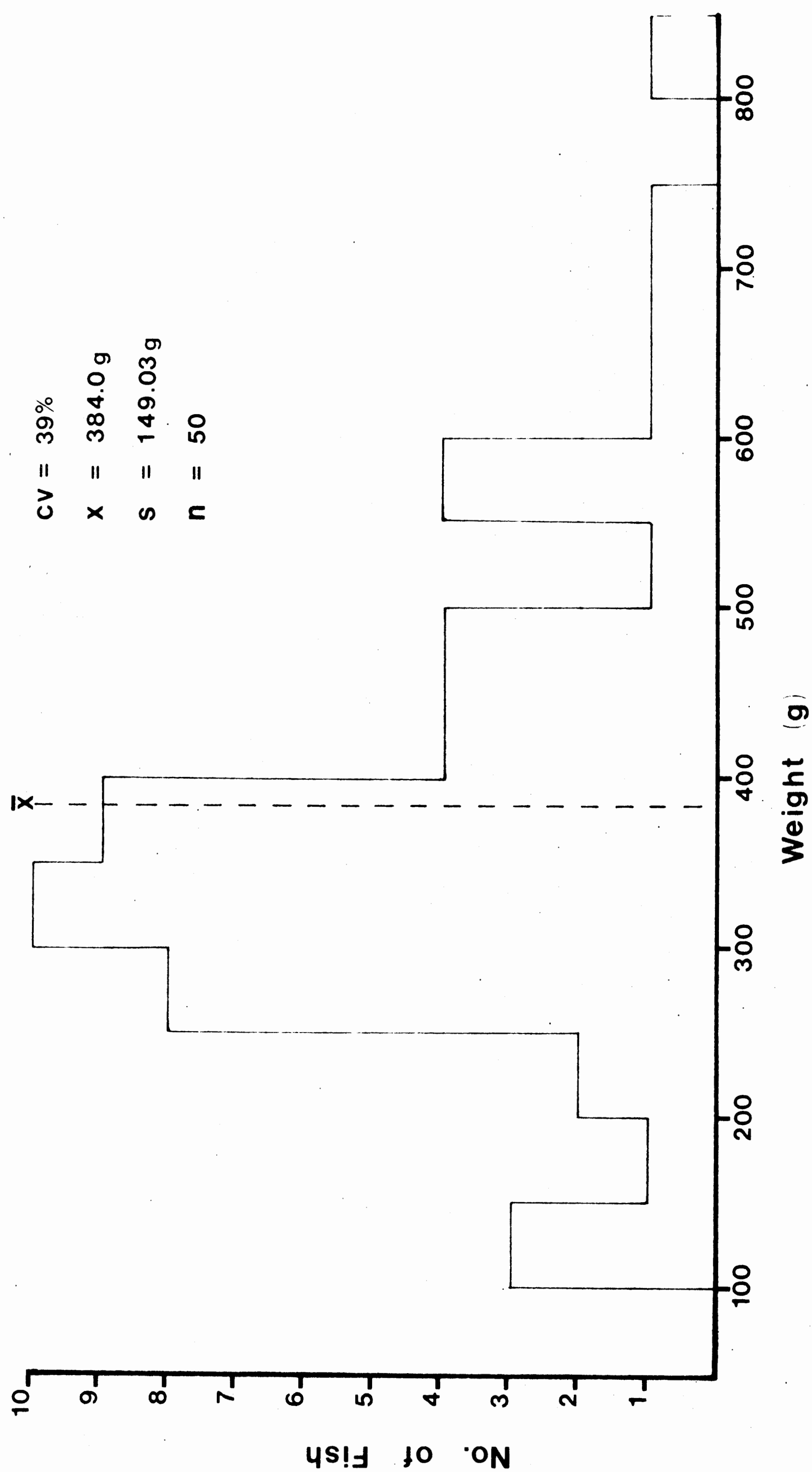

x̄
cv = 46%
x̄ = 246.9 g
s = 112.42 g
n = 50
No. of Fish
Weight (g)
10
9
8
7
6
5
4
3
2
1
100
200
300
400
500
600
700

Figure 28. Weight frequency distribution of channel catfish (pond 4) from the cage containing 10 tilapia-390 channel catfish.



cv = 39%
$\bar{x}$ = 306.7 g
s = 118.51 g
n = 50
$\bar{x}$
No. of Fish
Weight (g)
1
2
3
4
5
6
7
8
9
10
100
200
300
400
500
600
700

Figure 29. Weight frequency distribution of channel catfish (pond 4) from the cage containing 50 tilapia-350 channel catfish.

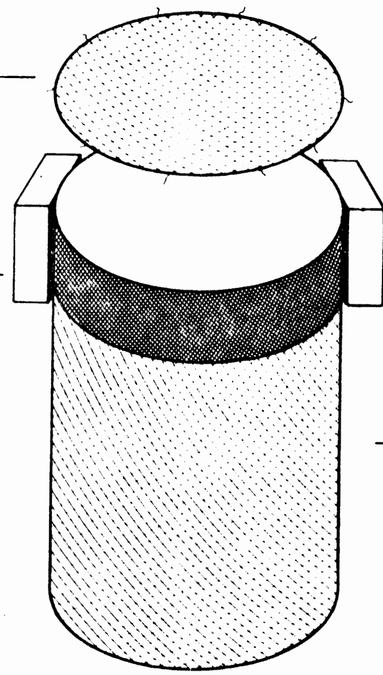

cv = 39%
x = 384.0 g
s = 149.03 g
n = 50
X̄
No. of Fish
10
9
8
7
6
5
4
3
2
1
100
200
300
400
500
600
700
800
Weight (g)

APPENDIX D

DIAGRAM OF CAGES USED FOR COMPUTING

THE PARTIAL BUDGET

Figure 30. An inexpensive, simply constructed cage suitable for fish culture (Jensen 1981b).



COST

45.7 m of plastic coated bell wire	$ 4.50
3, steel hoops	$10.80
3 mm vexar, 91 cm x 183 cm	$ 2.82
13 mm vexar, 122 cm x 427 cm	19.73
Floatation	$ 1.00
Labor, 2 hr. @ 3.00/hr.	$ 6.00
	$44.85

APPENDIX E

ANALYSIS OF VARIANCE FOR 1981 CHANNEL CATFISH-TILAPIA PRODUCTION DATA

Table 21. Analysis of variance, dependent variable: weight per channel catfish. N = 600

Source	df	MSE*	F	Prob. F
Trt.	2	152993	3.06	P = 0.0971
Pond	9	50057	3.16	P = 0.0010
Fish (Trt. Pond)	587	15838		

*MSE = Mean Square Error.

Table 22. Analysis of variance, dependent variable: K factor per channel catfish. N = 600

Source	df	MSE*	F	Prob. F
Trt.	2	0.11117	0.20	P = 0.8239
Pond	9	0.56184	13.54	P = 0.0001
Fish (Trt. Pond)	587	0.04148		

*MSE = Mean Square Error.

Table 23. Analysis of variance, dependent variable: percent harvestable channel catfish. N = 600

Source	df	MSE*	F	Prob. F
Trt.	2	1.12166	2.96	P = 0.1031
Pond	9	0.37944	1.59	P = 0.1126
Fish (Trt. Pond)	587	0.23792		

*MSE = Mean Square Error.

Table 24. Analysis of variance, dependent variable: weight per tilapia. N = 225

Source	df	MSE*	F	Prob. F
Trt.	1	22.559	0.00	P = 0.9857
Pond	6	65069.897	10.18	P = 0.0001
Fish (Trt. Pond)	217	6393.092		

*MSE = Mean Square Error.

Table 25. Analysis of variance, dependent variable: K factor of tilapia. N = 225

Source	df	MSE*	F	Prob. F
Trt.	1	0.04834	0.19	P = 0.6819
Pond	6	0.26094	0.53	P = 0.7864
Fish (Trt. Pond)	217	0.49383		

*MSE = Mean Square Error.

Table 26. Analysis of variance, dependent variable: percent harvestable tilapia. N = 225

Source	df	MSE*	F	Prob. F
Trt.	1	0.12034	0.14	P = 0.7254
Pond	6	0.88785	6.57	P = 0.0001
Fish (Trt. Pond)	217	0.13518		

*MSE = Mean Square Error.

Table 27. Analysis of variance, dependent variable: Total percent harvestable weight of channel catfish and tilapia per cage. N = 12

Source	df	MSE*	F	Prob. F
Trt.	2	5527.75	8.2207	P = 0.019
Pond	3	2144.75	3.1896	P = 0.105
Residual	6	672.41		

*MSE = Mean Square Error.

Table 28. Analysis of variance, dependent variable: weight coefficient of variation of channel catfish. N = 12

Source	df	MSE*	F	Prob. F
Trt.	2	34.433	1.1228	P = 0.385
Pond	3	9.370	0.3056	P = 0.821
Residual	6	30.666		

*MSE = Mean Square Error.

Table 29. Analysis of variance, dependent variable: net production of channel catfish. N = 12

Source	df	MSE*	F	Prob. F
Trt.	2	6.01	0.1585	P = 0.857
Pond	3	283.357	7.4652	P = 0.019
Residual	6	37.957		

*MSE = Mean Square Error.

Table 30. Analysis of variance, dependent variable: total amount of feed given per cage (kg). N = 12

Source	df	MSE*	F	Prob. F
Trt.	2	468.31	8.3662	P = 0.018
Pond	3	2646.53	47.2792	P = 0.000
Residual	6	55.97		

*MSE = Mean Square Error.

APPENDIX F

FEEDING RATIONALE FOR SMALL-SCALE CAGED POLYCULTURE

Feeding Rationale

The fish were fed daily, all that could be consumed in a 20-30 minute period (Neff and Barrett 1975) unless dissolved oxygen concentration dropped below 3 mg/1. At this level channel catfish often reduce feeding activity (Randolph and Clemens 1976). It was thought that the often used 5-10 minute feeding period (Jensen 1980a) which is more appropriate for open pond culture, was not sufficient for maximum growth in cages, especially in the cooler parts of the season. This practice resulted in increased feed consumption without appreciably affecting feed conversion efficiencies. Feeding on the basis of measured or projected body weight was also rejected as being inflexible and inefficient as was periodic sampling of fish which has been demonstrated to reduce feeding levels for several days after a sample was taken (Collins 1971).

Daily feeding is necessary to insure maximum production except when poor water quality exists. In a food deprivation study conducted by Randolph and Clemens (1978) it was observed that return to pre-deprivation feeding levels required about one day for each day missed feeding, but two days for each day missed were required to return to the previous rate of growth. Consequently, a less than daily feeding regime in localities where relatively short growing seasons exist may result in an unacceptable number of sub-harvestable sized fish.

The fish were fed in the late morning hours 0930 to 1030 to allow nightly low dissolved oxygen concentrations to increase and to allow the fish to digest the food during the afternoon when the dissolved oxygen is at the highest levels of the day (Boyd 1979). This was necessary because fish consume more oxygen one to eight hours after feeding (Lovell 1977) than at other times. Andrews and Matsuda (1975) found that 200 g channel catfish consume approximately 0.35 g O_2/kg body wt./hr. in the fasted state as compared with 0.53 g O_2/kg body wt./hr. as measured one hour after feeding. They also found that rate of oxygen consumption increased with rising temperature. The Q_{10}'s for the fasting and well fed curves were 2.3 and 1.9 respectively. The Q_{10} value is the factor by which oxygen consumption increases if the temperature is raised 10 C (Boyd 1979). Therefore these curves are as would be expected from van't Hoff's law which states that the change of reaction rate (proportional to oxygen consumption) is two to three fold for every 10 C change in temperature. Thus afternoon feeding would cause a greater oxygen demand to occur in the evening due to the ongoing digestive processes of the fish. Shrable et al. (1969) state that 32.41 percent of ingested food was found in channel catfish stomachs 12 hours after feeding when water temperature was 28 C. Therefore under marginal conditions, if fish were fed in the afternoon, stress or low oxygen induced mortality would be more likely to result than if fish were fed in the morning. It would also seem reasonable that uneaten food has a greater chance to oxidize during the height of diel dissolved oxygen fluctuation if it is fed in the morning thus reducing the potential oxygen demand placed on the pond by decaying food at night.

Some of these factors may appear to be minor; however, at times they can mean the difference between dissolved oxygen mortality and successful cage culture in small ponds.

VITA

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Master of Science

Thesis: POLYCULTURE OF CAGED CHANNEL CATFISH AND _TILAPIA AUREA_ IN SMALL PONDS

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